European Union Network for the Implementation and Enforcement of Environmental Law

IMPEL LANDFILL PROJECT
Inspection guidance book for Landfill inspection

A practical book with guidance on activities on landfills

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Introduction to IMPEL

The European Union Network for the Implementation and Enforcement of Environmental Law (IMPEL) is an international non-profit association of the environmental authorities of the European Union (EU) Member States, and of other European authorities, namely from acceding and candidate countries of the EU and European Economic Area (EEA). The association is registered in Belgium and its legal seat is in Brussels, Belgium.

IMPEL was set up in 1992 as an informal Network of European regulators and authorities concerned with the implementation and enforcement of environmental law. The Network's objective is to create the necessary impetus in the European Community to make progress on ensuring a more effective application of environmental legislation. The core of the IMPEL activities concerns awareness raising, capacity building and exchange of information and experiences on implementation, enforcement and international enforcement collaboration as well as promoting and supporting the practicability and enforceability of European environmental legislation.

During the previous years IMPEL has developed into a considerable, widely known organisation, being mentioned in a number of EU legislative and policy documents, e.g. the 8th Environment Action Programme that guide European environmental policy until 2030, the EU Action Plan: "Towards a Zero Pollution for Air, Water and Soil" on Flagship 5 and the Recommendation on Minimum Criteria for Environmental Inspections.

The expertise and experience of the participants within IMPEL make the network uniquely qualified to work on both technical and regulatory aspects of EU environmental legislation.

Information on the IMPEL Network is also available through its website at: www.impel.eu

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Executive summary:

The Council Directive 1999/31/EC on the landfill of waste (as amended by Directive (EU) 2018/850) and the Council Decision of May 2002 establishing criteria and procedures for the acceptance of waste at landfills (2003/33/EC) set standards for the authorisation, design, operation, closure and aftercare of landfills.

Improving implementation of EU law is a high priority objective of both the European Commission and IMPEL. Recent reports on implementation of EU waste legislation have shown that "*implementation and enforcement of EU waste law remain poor particularly regarding the Waste Framework Directive, the Landfill Directive and the Waste Shipment Regulation*".

The objectives of the project have been:

- identification of good inspection practices and developing guidance;
- improve cooperation between IMPEL member countries to work towards a consistent regulatory and enforcement regime;
- providing feedback to policy makers on the effectiveness of the various approaches and practices in the field of permitting and inspection of landfill sites in the IMPEL member countries.

Throughout the duration of the project, site visits, joint inspection and training sessions have been performed. In various chapters of this Guidance, examples of best practice are mentioned and described. These examples have been derived from both from technical and legal requirements in the Member States, where these have been identified and described by the authors, as well as from the authors' own practical experience. Therefore, a complete enumeration of all best practice examples from Member States cannot be expected.

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ACRONYMS AND ABBREVIATIONS

BAT	Best Available Technology
BC	Basic Characterization
CLP	Regulation (Ec) No 1272/2008 On The Classification, Labelling And Packaging Of Substances And Mixtures
CQA	Construction Quality Assurance
CQAP	Construction Quality Assurance Plan
DOC	Dissolved Organic Carbon
ELV	Emission Limit Value
EMAS	Community Eco-Management And Audit Scheme
EMS	Environmental Management System
EU	European Union
EWC	European Waste Catalogue
HP	Hazardous Properties
IED	Industrial Emission Directive
ANC	Acid neutralizing Capacity
PCB	Polychlorinated Biphenyls
E-PRTR	European Pollutant Release And Transfer Register
REACH	Registration, Evaluation, Authorization And Restriction Of Chemicals
TDS	Total Dissolved Solids
TOC	Total Organic Carbon
VOC	Volatile Organic Compounds
WAC	Waste Acceptance Criteria

1. INTRODUCTION

1.1. Purpose and context

Improving implementation of EU law is a high priority objective of both the European Commission and IMPEL. Recent reports on implementation of EU waste legislation have shown that "*implementation and enforcement of EU waste law remain poor particularly regarding the waste framework directive, the landfill directive and the waste shipment regulation*".

According to the waste management hierarchy, landfill is the least preferable option and should be limited to the necessary minimum.

Directive (EU) 2018/850 states that Member States shall endeavor to ensure that as of 2030, all waste suitable for recycling or other recovery, in particular municipal waste, shall not be accepted at a landfill, with the exception of waste for which landfilling delivers the best environmental outcome in accordance with Article 4 of Directive 2008/98/EC.

Furthermore, Member States shall take the necessary measures to ensure that by 2035 the amount of municipal waste landfilled is reduced to 10% or less of the total amount of municipal waste generated (by weight).

Where waste needs to be landfilled, it must be sent to landfills which comply with the requirements of Directive 1999/31/EC on the landfill of waste.

The Council Directive 1999/31/EC on the landfill of waste sets standards for the authorization, design, operation, closure and aftercare of landfills.

The acceptance criteria and the acceptance process are further specified in Council Decision 2003/33/EC. This includes a detailed description of waste characterization procedures, limit values for waste composition and leaching behavior, as well as acceptance procedures to be executed at each landfill site.

Member States must ensure that existing landfill sites may not continue to operate unless they comply with the provisions of the Directive and Council Decision.

Within the last years, important efforts have been taken in order to meet the established legal requirements. However, infringement cases, complaints and petitions received by the European Commission show that there are deficits in implementation.

The objectives of the Landfill inspection project have been:

- Identification of good inspection practices, including developing guidance and a checklist;
- Cooperation (and helping each other) between IMPEL member countries to work towards a consistent regulatory and enforcement regime;
- Feedback to policy makers on the effectiveness of various approaches and practices in the field of permitting and inspection of landfill sites in the IMPEL member countries;
- Improvement of enforcement cooperation between authorities concerned with landfills.

These main project objectives have been achieved by:

- Carrying out joint inspections in landfill across Europe to exchange experiences and knowledge: several Member States participated in the joint inspections with their inspectors, dealing with the main environmentally critical aspects of landfill management;
- Organizing a training session with an expert from the UK Environment Agency;
- Developing Guidance and a checklist to be used in the preparation of an inspection;
- Extending the use of Basecamp under the IMPEL website for experts in all IMPEL member Countries as an exchange platform for information and specific questions, discussions etc.

- Handing out a survey to highlight the gaps of the Landfill Directive across EU, which results are contained in the IMPEL Report "*Landfill Directive Implementation - Analysis of the gaps found during the running of the Landfill Project*".

The following picture shows where the joint inspections have been performed during the project:

Figure 1: Landfill visited along the project

1.2. Structure of the Guidance book

The Guidance is structured in Chapters as follows:

Chapters 1-2) are dedicated to the presentation of the relevant legislation about landfill and give additional basic pieces of information.

Chapter 3) provides an overview of the main contents of the steps of the organization of an environmental inspection (preparation, execution, reporting), according to the Industrial Emissions Directive (IED).

Chapters 4-10) give technical details for specific subjects which have to be included in a permission and which should be covered during a landfill inspection; the topics focused in the Guidance are the following.

- Waste acceptance criteria for the landfill's classification of waste and sampling procedures.
- Non-reactive waste including acceptance, pretreatment and storage
- Asbestos including acceptance and storage
- Biogas control and odors.
- Protection of soil and groundwater.
- Water control and leachate management.
- Top and bottom layers.
- Final report after completion.
- Financial guarantees.
- Landfill operator self-monitoring and annual report.

Reference is given to existing guidance documents and tools in EU member states.

Annex 1 consists of a checklist to be used for the preparation of the landfill inspection

Annex 2 consists of an inspection checklist to be used on site

Annex 3 includes an example of a detailed checklist on waste acceptance

Annex 4 defines the minimum content of a self-monitoring plan for a landfill installation.

1.3. Lifecycle of a landfill

The lifecycle of a landfill is essentially divided into three phases. These are shown in the following diagram, starting with construction and ending with final release from aftercare.

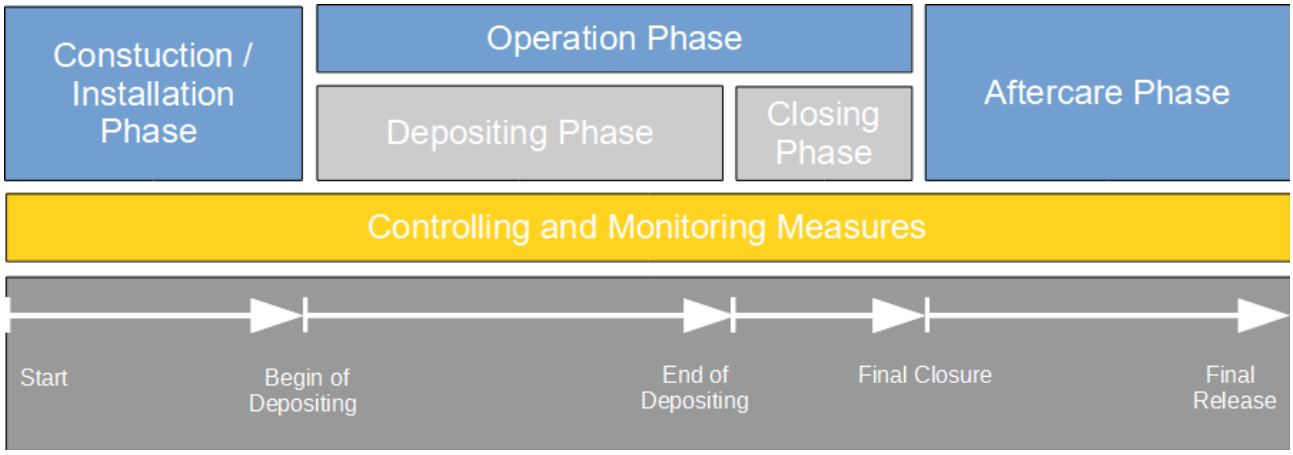

Figure 2: Lifecycle of a landfill

2. LANDFILLS LEGISLATIVE REFERENCES

2.1. Landfill directive

Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste (Landfill Directive) came into force on 16 July 1999. The deadline for implementation of the legislation in the Member States was 16 July 2001. All new and existing landfills had to fully comply with the requirements of Directive 1999/31/EC at the latest by 16 July 2009 or as indicated in the accession treaties (for new Member States).

To underpin the EU's transition to a circular economy, the European Commission adopted a Circular Economy Package on 2 December 2015, which included Directive (EU) 2018/850 amending Directive 1999/31/EC.

One of the drivers of the amended Directive is a progressive reduction of landfilling to prevent detrimental impacts on human health and the environment and to ensure that economically valuable waste materials are gradually and effectively recovered through proper waste management and in line with the waste hierarchy as laid down in Directive 2008/98/EC.

In this respect, Directive (EU) 2018/850 introduces restrictions on landfilling from 2030 of all waste that is suitable for recycling or other material or energy recovery and seeks to limit the share of municipal waste landfilled to 10% by 2035.

By 31 December 2024, the Commission shall review the 2035 10% target with a view to maintaining or, if appropriate, reducing it, considering quantitative target per capita on landfilling, introducing restrictions to the landfilling of non-hazardous waste other than municipal waste

It also introduces rules on calculating the attainment of municipal waste targets and requires EU countries to put in place an effective quality control and traceability system for municipal waste landfilled. Member States should take all necessary measures to ensure that only waste that has been subject to treatment is landfilled.

The aim of the consolidated version of the Directive 1999/31/EC is "*to ensure a progressive reduction of landfilling of waste, in particular of waste that is suitable for recycling or other recovery, and, 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*".

The Directive 1999/31/EC and the Decision 2003/33/EC on acceptance criteria set standards for the authorization, design, operation, closure and aftercare operations at landfills. Detailed description on acceptance criteria and the acceptance process have been set by Council Decision 2003/33/EC. This Decision entered into force on 16 July 2004 and the limit values had to be applied in the Member States at the latest by 16 July 2005.

Member States must ensure that existing landfill sites may not continue to operate unless they comply with the provisions of the Directive.

Landfills are distinguished into three classes:

- Landfills for hazardous waste;
- Landfills for non-hazardous waste (these landfills may be used for (i) municipal waste (ii) non-hazardous waste of any origin, which fulfil the criteria for the acceptance of waste at landfill for non-hazardous waste set out in accordance with annex II stable, non-reactive hazardous waste (e.g. solidified, vitrified) with leaching behavior equivalent to those of the non-hazardous waste referred to in point (ii) which fulfil the relevant acceptance criteria set out in accordance with Annex. These hazardous wastes shall not be deposited in cells destined for biodegradable non-hazardous waste);

- Landfills for inert waste (waste that does not undergo any significant physical, chemical or biological transformations).

The Landfill Directives excludes the following activities:

- the spreading of sludges, including sewage sludges and sludges resulting from dredging operations and similar matter on 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 and of non-hazardous sludges in surface water including the bed and its subsoil;
- the management of waste from land-based extractive industries, that is to say, the waste arising from the prospecting, extraction, including the pre-production development stage, treatment and storage of mineral resources and from the working of quarries.

The following types of wastes may not be accepted at a landfill:

- liquid waste;
- waste which is explosive, corrosive, oxidising, highly flammable or flammable, as defined in Annex III to Directive 91/689/EEC;
- hospital and other clinical wastes arising from medical or veterinary establishments, which are infectious;
- used tyres, with certain exceptions;
- any other type of waste which does not meet the acceptance criteria laid down in Annex II of the directive;
- waste that has been separately collected for preparing for re-use and recycling with the exception of waste resulting from subsequent treatment operations of the separately collected waste for which landfilling delivers the best environmental outcome.

The Directive sets up a system of operating permits for landfill sites. Applications for permits must contain the following information:

- the identity of the applicant and, in some cases, of the operator;
- a description of the types and total quantity of waste to be deposited;
- the capacity of the disposal site;
- a description of the site;
- the proposed methods for pollution prevention and abatement;
- the proposed operation, monitoring and control plan;
- the plan for closure and aftercare procedures;
- the applicant's financial security;
- an impact assessment study, where required under Council Directive 85/337/EEC on the assessment of the effects of certain public and private projects on the environment.

Directive 1999/31/EC on the landfill of waste has been recently amended by the Directive (EU) 2024/1785 (amending Directive 2010/75/EU on industrial emissions).

2.2. Council Decision of 19 December 2002 (2003/33/EC - WAC)

Council Decision 2003/33/EC contains criteria and procedures for the acceptance of waste at landfills. Procedure for the acceptance of waste at landfills includes three steps:

- Basic characterization.
- Compliance testing.
- On-site verification.

For more detailed information about the content see chapter 4 to 6.

2.3. Waste Framework Directive (WFD)

Directive 2008/98/EC sets the overarching legislative framework and the basic concepts and definitions related to waste management (such as definitions of waste, recycling, recovery ecc.). It was amended by the Directive 850/2020 and "*lays down measures to protect the environment and human health by preventing or reducing the generation of waste, the adverse impacts of the generation and management of waste and by reducing overall impacts of resource use and improving the efficiency of such use, which are crucial for the transition to a circular economy and for guaranteeing the Union's long-term competitiveness*".

The Directive lays down some basic waste management principles:

- The 'waste hierarchy', a priority order set among waste prevention and management options; the 'polluter pays principle' (ensuring that the costs of preventing, controlling and cleaning up pollution are reflected in the cost of goods).
- The precautionary principle.
- The proximity principle.

Figure 3: Waste hierarchy

The Directive explains when waste ceases to be waste and becomes a secondary raw material (so called End-of-Waste criteria), and how to distinguish between waste and by-products.
The Directive sets binding targets to be achieved by 2020, 2025 and 2030 for preparing for reuse and recycling of municipal waste.

It also requires Member States to set up separate collection of at least paper, metal, plastic and glass, and, by 1 January 2025, for textiles, and to draw up waste management plans and waste prevention programmes.

2.4. List of Waste and waste classification

The Commission Decision 2000/532 establishes the European List of Waste; a consolidated version of the List of Waste has existed since 2000 and has been revised by Commission Decision 2014/955/EU (which also adapt the Decision to the new legislation on chemicals - CLP), in order to adapt the list to scientific progress and align it with developments in chemicals legislation.

It contains rules about classifying different types of waste according to chapters in the list of waste and the content of one or more substances with hazardous properties. A waste is defined by a six digit code. The code is identified by using steps described in the Annex to the Council decision. The list of waste is divided into 20 chapters.

Waste are classified to be hazardous if it contains substances that have hazardous properties. The hazardous properties are listed in Annex III in the Waste Framework Directive (2008/98/EC). There are 15 properties (HP1-HP15). The content is calculated according to the legislation on chemicals and often contains concentration-based limit values.

The list of waste recognizes three types of entries:

- 'Absolute hazardous entries': Wastes which are assigned to absolute hazardous entries cannot be allocated to non-hazardous entries and are hazardous without any further assessment;
- 'Absolute non-hazardous entries': Wastes which are assigned to absolute non-hazardous entries cannot be allocated to hazardous entries and are non-hazardous without any further assessment;
- 'Mirror entries', where waste from the same source might under the list of waste be allocated to a hazardous entry or to a non-hazardous entry depending on the specific case and on the composition of the waste.

The European Commission Notice on technical guidance on the classification of waste (2018/C 124/01) provides clarifications and guidance to national authorities, including local authorities, and businesses (e.g. for permitting issues) on the correct interpretation and application of the relevant EU legislation regarding the classification of waste, namely identification of hazardous properties, assessing if the waste has a hazardous property and, ultimately, classifying the waste as hazardous or non-hazardous

Council Regulation (EU) 2017/997 of 8 June 2017 amends Annex III of the Directive 2008/98/EC as regards the hazardous property HP 14 'Ecotoxic''. HP 14 'Ecotoxic' is defined as waste which presents or may present immediate or delayed risks for one or more sectors of the environment.

2.5. Industrial Emissions Directive

Some landfills covered by Council Directive 1999/31/EC on the landfill of waste also fall within the scope of Council Directive 2010/75/EU concerning Industrial Emissions (integrated pollution prevention and control) the successor of the IPPC directive. The Industrial Emission Directive (IED) entered into force on 6 January 2011 and had to be transposed into national legislation by member states by 7 January 2013.

Landfills that fall within the scope of Industrial Emission Directive are the following categories of activities in annex 1:

- 5.4 Landfills as defined in Article 2(g) of Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste, receiving more than 10 tonnes of waste per day or with a total capacity exceeding 25 000 tonnes, excluding landfills of inert waste;

- 5.6 Underground storage of hazardous waste with a total capacity exceeding 50 tonnes.

For these landfills both the Landfill Directive and the Industrial Emissions Directive have to be taken into account. This means the following additional requirements for these landfills:

- **Updating of permit conditions**: Article 21 of the Industrial Emission Directive requires competent authorities to periodically reconsider permit conditions and where necessary to ensure compliance with the Directive to update those conditions. Within 4 years after the publication of Decision on BAT conclusions the competent authority shall ensure that (a) all the permit conditions for the installation concerned are reconsidered and if necessary updated to ensure compliance with the Directive (in particular Article 15(3) and (4) where applicable) (b) the installation complies with those permit conditions. Although landfills are included within the scope of the IED, no BAT conclusions exist for landfills owing to the coverage of this activity under Council Directive 1999/31/EC, pursuant to which its requirements are deemed to constitute BAT.
- **Applications for permits**: Article 12 of the Industrial Emission Directive specifies information that must be included in the application for a permit. Much, but not all of this information is also required under the Landfill Directive (Art. 7). On the other hand some requirements are specific to the Landfill Directive (see Article 7(i)). It should be noted that the IED requires information on the sources of emissions from the installation as well as the nature and quantities of foreseeable emissions into each medium and identification of significant effects on the environment. An application for a landfill has to comply with both the provisions of Article 12 of the Industrial Emission Directive and Article 7 of the Landfill Directive.
- **Access to information and public participation in the permit procedure**: Article 24 of the Industrial Emissions Directive requires that permit applications for new or substantially changed installations are made available to the public. The public is given the right to comment on them before the competent authority reaches its decision. The decision, a copy of the permit, permit updates and the results of release monitoring must be made available to the public. No corresponding provision exists in the Landfill Directive. Any landfill also covered by the Industrial Emission Directive must be made subject to public participation and information as outlined above.
- **Environmental inspections**: Article 23 of the Industrial Emission Directive requires that member states shall ensure that all installations are covered by an environmental inspection plan at national, regional or local level and shall ensure that this plan is regularly reviewed and where appropriate updated. The period between two site visits shall be based on a systematic appraisal of the environmental risks of the installations concerned and shall not exceed 1 year for the installations posing the highest risk and 3 years for installations posing the lowest risks.

  Following each visit the competent authority shall prepare a report describing the relevant findings regarding compliance of the installation with the permit conditions and conclusions on whether any further action is necessary. The report shall be notified to the operator concerned within 2 months of the site visit taking place. The report shall be made publicly available by the competent authority in accordance with Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on public access to environmental information within 4 months of the site visit taking place.

Within the framework of the New Circular Economy Action, the Industrial Emissions Directive has been amended by the Directive (EU) 2024/1785, envisaging the integration of circular economy practices in upcoming Best Available Techniques reference documents.

Due to the technical developments and innovation that have taken place since the adoption of Directive 1999/31/EC, more effective techniques for protecting human health and the environment are now available. The Directive (EU) 2024/1785, amending Directive 2010/75/EU on Industrial Emissions and Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste, envisages the adoption of BAT conclusions on landfills under Directive 2010/75/EU, hence addressing the

key environmental issues related to the operation of waste landfills, including significant emissions of methane.

Directive 1999/31/EC should therefore allow for the adoption of BAT conclusions on landfills under Directive 2010/75/EU. Directives 2010/75/EU and 1999/31/EC should therefore be amended accordingly.

The amendment to Article 1 of Council Directive 1999/31/EC on the landfill of waste aims at allowing the adoption of BAT conclusions on landfills under this Directive.

Special case: landfill, baseline report, definite closure and remediation

Article 22 (2) of IED requires that the operator shall prepare and submit to the competent authority a baseline report before starting operation if the activity involves the use, production or release of relevant hazardous substances and having regard to the possibility of soil and groundwater contamination at the site of the installation. This baseline report shall contain the information necessary to determine the state of soil and groundwater contamination so as to make a quantified comparison with the state upon definitive cessation of activities provided for under Art. 22 paragraph 3. The baseline report shall contain at least the following information […]

a) information on the present use and, where available, on past uses of the site;
b) where available, existing information on soil and groundwater measurements that reflect the state at the time the report is drawn up or, alternatively, new soil and groundwater measurements having regard to the possibility of soil and groundwater contamination by those hazardous substances to be used, produced or released by the installation concerned.

Article 22 (3) of IED requires that upon definitive cessation of the activities, the operator shall assess the state of soil and groundwater contamination by relevant hazardous substances used, produced or released by the installation. Where the installation has caused significant pollution of soil or groundwater by relevant hazardous substances compared to the state established in the baseline report referred to in paragraph 2, the operator shall take the necessary measures to address that pollution so as to return the site to that state. For that purpose, the technical feasibility of such measures may be taken into account […].

At first, it should be noted that waste does not fall within the scope of the CLP-Regulation and therefore is not a hazardous substance within the meaning of this Regulation. Thus, only hazardous substances (CLP) which are used in relevant quantities at the landfill, e.g. chemicals, fuels, etc., could be considered for the analysis of a baseline report.

Furthermore, the essential characteristic of a landfill is to remain exactly at this constructed site, to be operated, closed, turned over to aftercare and finally released. Therefore the return to the original state (baseline) on exactly the same area would not be possible. Technical requirements as site search, geological and hydrogeological prerequisites, risk assessment, investigations of protected resources, conditions of construction, monitoring and performance of required measures during all phases of landfill lifecycle (figure 2) are described and discussed in the following chapters.

The basic request of Art. 22 IED is already satisfied by all these measures.

2.6. Monitoring requirements

Landfill Directive

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:

[…]

(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 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 are to be sent to the competent authorities for the purpose of demonstrating compliance with permit conditions and increasing the knowledge on waste behavior in the landfill.

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

IED Directive

Article 14 "Permit conditions"

Member States shall ensure that the permit includes all measures necessary for compliance with the requirements of Articles 11 and 18. Those measures shall include:

c. Suitable emission monitoring requirements specifying (i) measurement methodology, frequency and evaluation procedure.

d. An obligation to supply the competent authority regularly, and at least annually, with: (i) information on the basis of results of emission monitoring referred to in point (c) and other required data that enables the competent authority to verify compliance with the permit conditions.

Article 16 Monitoring requirements

1. The monitoring requirements referred to in Article 14(1)(c) shall, where applicable, be based on the conclusions on monitoring as described in the BAT conclusions.

2. The frequency of the periodic monitoring referred to in Article 14(1)(e) shall be determined by the competent authority in a permit for each individual installation or in general binding rules.

Without prejudice to the first subparagraph, periodic monitoring shall be carried out at least once every 5 years for groundwater and 10 years for soil, unless such monitoring is based on a systematic appraisal of the risk of contamination.

Annex 4 includes a proposal for the minimum content of a landfill operator self-monitoring plan.

3. INSPECTION ORGANIZATION

The aim of the inspection is to verify compliance with the conditions laid down in the permit, with provisions of the Landfill directive and Council Decision and, where applicable, with further conditions from other areas of environmental regulation. The present chapter describes the basic requirements for an inspection. More detailed descriptions can be found in the following chapters.

3.1. Legal requirements

The following Articles of the Landfill Directive give an overview of which information normally has to be set out in a permit application and in a control/monitoring programme. All of this information should be used to prepare an on-site landfill inspection.

Permit (application)

Article 7, Application for a permit according to the directive a application shall at least contain 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 hydro geological 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) impact assessment 85/337/EEC
(i) financial security by the applicant or any other equivalent provision

Control and Monitoring programme

Article 12, control and monitoring procedures in the operational phase

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

Annex III contains conditions about:

2. meteorological data
3. emission data: water, leach ate and gas control
4. protection of groundwater
5. topography of the site: data on landfill body
6. specific requirements for metallic mercury

Notification of operator to competent authority of any adverse environmental effects

Article 12 (b):

(b) The operator shall notify the competent authority of any significant adverse environmental effects revealed by the control and monitoring procedures

Report all monitoring results to the competent authorities

Article 12 (b):

(b) 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.

3.2. Inspection preparation[1]

There are different types of inspections to be performed at an installation. i.e.:

- Regular, announced on-site inspection (according to an inspection plan).
- Regular, unannounced inspection.
- Inspections in case of accidents, incidents and complaints.

Collection and evaluation of all existing pieces of information about the installation is essential for the success of the inspection. It allows the easier formulation of targeted, oriented questions regarding those landfill operations with the highest potential for non-compliance with the conditions set out in the permit.

Examples of information to be collected are listed below:

- Environmental permit.
- Permit application (technical data).
- Maps.
- Reports of previous inspections.
- Environmental reports submitted by the operator, including monitoring reports.
- Reports sent by the operator (incidents, modifications, requests, etc.).
- Data from Pollutant release and trade register (E-PRTR) and other registers such as register of polluting substances into air, register of waste producers.
- Complaints received about the installation.
- Information received from other competent authorities.
- Information available on the website of the operator.

The inspection team shall decide on the type of inspection and on the resources, including staff and equipment, which will be assigned to the task.

Analysis of technical data acquired during the desk study allows better preparation of the checklist and of the Inspection Agenda to be used during the site visit.

Based on the evaluation of the collected information, the following has to be prepared:

- a comprehensive questionnaire which will be used for the operator's interview;
- a checklist to facilitate the inspection;
- an outline of the "critical" ELVs (i.e. those parameters which significantly contribute to the pollution load coming out of the installation);
- the list of BATs (according to the issued permit) which the operator should have implemented and be operating against;
- documentation to be provided by the operator (e.g. self-monitoring records, annual reports submitted to the authorities);
- inspection notes and report templates (tailor-made for the installation) to be completed at the end of the inspection;
- agenda of the inspection.

[1] See Annex I: Desk study check list

3.3. On-site inspection

The first step of the inspection visit is an initial/starting meeting, when the inspection team leader introduces the team members and explains the purpose of the visit.

The inspection agenda is presented by the inspection team leader to agree on the stages of verification and define the staff to be made available by the company to follow one or more phases of the inspection. It could be helpful to start the inspection by presenting a list of documents that are (or might be) needed during the inspection. It is worth asking the operator to describe the status of the plant (to assess potential modifications performed after a previous inspection) and to briefly evaluate the results of previous monitoring assessments.

General notes on carrying out the inspection

- Identify yourself. Clearly introduce yourself and show your identification card at the beginning of each inspection.
- Explain purpose of the visit.
- Use a checklist to perform the inspection (the operating/environmental conditions set in the issued permit will be the guidance throughout the inspection).
- If necessary, take samples, and/or define the samples that should be taken by a certified laboratory.
- Always record your inspection by taking photographs and/or videos. They are fundamental as a proof in court.
- Create minutes of the inspection containing strengths and weaknesses.

When checking the administration (installation records), the following should be verified:

- Waste input/output register.
- Maintenance operations register.
- Self-monitoring register.
- Communications to the Competent Authority (incidents etc.).
- EMS Procedures.

On-site technical inspections could include the following visual controls:

- Entrance/reception area and weighbridge.
- Fencing.
- Waste acceptance and handling of waste.
- Intermediate waste storage.
- Steepness of slopes.
- Condition of the top layer and temporary layers when required.
- Handling of waste.
- Storage of waste.
- Condition of leachate collection system, condition of gas collection and recovery system.
- Condition of rainwater collection and drainage system.
- Leachate and rainwater management.

It must be checked that all BATs as prescribed in the permit have been implemented and are being followed, and the corresponding Emission Limit Values (ELVs) are being met.

To support Member States' enforcement actions and inspections concerning the application of EU waste legislation, the European Commission published a Practical Manual[2] which includes several queries about landfill inspection as follows. These queries can be used as part of a checklist and focus on:

- Waste acceptance procedures.
- Basic characterization.
- Compliance testing documents.
- Documentation of the waste flow: traceable, complete and consistent (identification form, single weighing bridge documents, landfill internal monthly list, report of type and quantity of waste to the competent authority).
- Self-monitoring results (leachate volume, leachate composition, volume and composition of surface water, potential gas emissions and atmospheric pressure in line with the permit, national legislation or the landfill directive).
- Waste handling.
- Biodegradable waste.
- Asbestos waste.
- Gypsum waste.
- Volatile emissions hazardous to environment.

Everything that can be found during inspections may be worth being collected and treated as evidence and must be attached to the final report.

The inspection visit ends with a concluding meeting when the observed strengths and weaknesses are discussed and minutes of the inspection are drafted and signed.

3.4. Post inspection and reporting

After the inspection, a written report is produced by the inspection authority.

The following post-inspection activities can be performed:

- Save inspection records in a database.
- Determine if any changes to the permit are necessary.
- Determine environmental impact.
- Prepare written information (to the operator).

In case of non-compliances detected / identified, the following general procedures are possible:

- Issuing an administrative order.
- Issuing an administrative ruling in terms of permit conditions, i.e. setting new additional conditions within a permit.
- Issuing sanctions, penalties or fines; and
- In particularly serious cases, withdrawal of the permit.

Member State legislation has to be consulted to check what kind of procedure has to be applied in case of irregularities and non-compliance.

In case of an IED inspection, the following applies in accordance to Article 23(6) of IED:

[2] https://ec.europa.eu/environment/pdf/waste/framework/Practical%20manual%20on%20permitting%20and%20inspection.pdf

After the inspection, the inspector has to draft a final inspection report describing the relevant findings regarding compliance of the installation with the permit conditions and conclusions on whether any further action is necessary.

The report shall be notified to the operator concerned within 2 months of the site visit taking place and shall be made publicly available by the competent authority in accordance with Directive 2003/4/EC of the European Parliament and of the Council of 28 January 2003 on public access to environmental information within 4 months of the site visit.

The main contents of such a report are the following:

1. Baseline of the inspection

- Inspection basis (permit, legal regulations).
- Competent inspection authority, cooperating inspection authorities.
- Class of landfill: Inert, non hazardous, or hazardous wastes.
- Phase: Pre-operational, open landfill, pre-closure, post-closure.
- Operator (Name of the company).
- Address.
- Date of inspection.
- Length of inspection time.
- Scope of the inspection (e.g. integrated inspection, media that were inspected, parts of the installation that were inspected).
- Type of inspection (routinary, non routinary, control/recheck in case of significant non-compliances).

2. Inspection's results

- No or only minor non-compliances.
- Significant or relevant non-compliances.
- Severe non-compliances.

3. Recommended corrective measures

- Minor corrective measures.
- Significant or major corrective measures.
- Severe corrective measures.

The inspection report and any other additional material used for the preparation of the inspection should be archived and made accessible to any relevant authorities for their information.

4. WASTE ACCEPTANCE CRITERIA AND SAMPLING PROCEDURES

The waste acceptance procedures at a landfill have to be split into two parts: the pre-acceptance and the acceptance procedures. Waste treatment sites require information and/or samples to be provided prior to the transport of waste to the site to be sure that the waste is within the requirements of the site licence (thresholds / limitations). *Pre-acceptance* includes (in most cases) taking a sample (or various samples), completing an identification form, carrying out the chemical analysis and then assessing whether the waste can be accepted at the landfill or not.

Pre-acceptance is split into a *basic characterisation* (mostly performed by the waste producer) and the more simplified *compliance testing* (usually performed by the waste producer) aiming to determine if the waste complies with the results of the basic characterisation and the relevant acceptance criteria. The basic characterisation and analysis of a sample is required for each batch of incoming waste, in case these wastes are not regularly generated in the same process, in the same installation and are not part of a well-characterised waste stream.

Particular attention has to be paid to mirror-code waste, as the analysis also has to determine whether the waste is hazardous or not and the relevant hazardous properties as well.

When the waste is accepted at the landfill, the facility signs a declaration and sends a copy of this to the waste producer.

The last activity performed by the operator is the *on-site verification*: each load of waste delivered to a landfill is visually inspected before and after unloading and the required documentation is checked. Sometimes sampling and analysis are performed by the operator.

4.1. Legal requirements in Landfill Directive and Council Decision

Acceptance criteria for landfills

In the Council decision of 19 December 2002, establishing criteria and procedures for the acceptance of waste at landfills, most of the provisions on the subject of acceptance of waste at landfills are given. It defines fundamental requirements for basic characterization of the waste and for testing. In paragraph 2 of the annex "*waste acceptance criteria*" criteria for the acceptance of waste at each landfill class (including underground storage) are given.

There are limit values for the following six types of landfills:

- Landfill for inert waste (leaching values and total content).
- Landfill for non-hazardous waste without testing (municipal waste).
- Landfill for non-hazardous waste in same cell as stable non-reactive hazardous waste (leaching values and total content).
- Landfill for non-hazardous gypsum waste without testing (in special cells without biodegradable waste).
- Landfill for non-hazardous waste that accepts hazardous waste (leaching values and other criteria).
- Landfill for hazardous waste (leaching values and other criteria).

Waste classification

Waste classification is based on the European List of Waste (*Commission Decision 2000/532 replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste*) and on the hazardous properties. Member states have implemented this European legislation in national law, mostly as ordinances and regulations.

The European Commission issued the "*Commission notice on technical guidance on the classification of waste (2018/C 124/01)*"[3], that helps national authorities, local authorities, and businesses (e.g. for permitting issues) to correctly interpret and apply EU law on the classification of waste.

It provides:

- A comprehensive overview of relevant EU law.
- Examples of waste types for which classification is considered difficult by stakeholders.
- Step-by-step information on how to assess whether waste displays hazardous properties and on how to classify it.

The classification of waste (by using the correct EWC) defines whether a waste has to be treated before going to a landfill or if can be directly landfilled at a specific landfill class (type).

If the classification is incorrect, it could mean that waste with hazardous properties ends up in a landfill with a lower level of protection. This could especially be the case when the waste is considered non-hazardous without appropriate sampling and analyses being done. For example waste with a "mirror-code', which ends with a EWC-code of 99, which is irregularly generated, or if the waste is a mix of wastes such as EWC-code 17.05.XX.

The Commission Decision 2014/955 has amended Decision 2000/532, replacing the Annex containing the list of waste referred to in article 7 of Directive 2008/98/EC.

A Guidance[4] on waste classification has been also issued by the Italian EPA's network (SNPA).

Sampling of waste

Sampling and testing of waste is covered by Article 4 of the Council Decision 2003/33/EC. Section 3 of the Annex comprises the issues of sampling and testing methods.

Section 3 of the Council Decision Annex indicates that "*sampling and testing for basic characterisation and compliance testing has to be carried out by independent and qualified persons and institutions*"; laboratories shall have proven experience in waste testing and analysis and an efficient quality assurance system. According to the Italian transposition of the Council Decision, laboratories have to be accredited according to the Standard EN ISO 17025:2018.

A list of testing methods (to determine *general waste properties* and regarding the *digestion of raw waste*) is to be amended in due time when more CEN standards are available.

The more heterogeneous a certain kind of waste is, the more samples have to be taken to ensure that the sample(s) is (are) fully representing this waste. The size of the waste particles and the size of the waste population also affects the number of samples to be taken.
Many other factors also play an important role in the way a waste should be sampled to give an correct answer to how high the content of (potential) pollutants are.

Analytical results that are not based on a sampling plan must not be considered s reliable representation of the waste. A European Standard EN 14899:2006 has been developed for the purpose of waste characterization. This European Standard specifies the procedural steps to be taken in the preparation and application of a sampling plan.

[3] https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2018.124.01.0001.01.ENG&toc=OJ:C:2018:124:TOC

[4] https://www.snpambiente.it/wp-content/uploads/2021/07/Delibera-105-2021-LLGG-Classificazione-rifiuti.pdf

When Council Decision 2003/33/EC came into force, the European Standard EN 14899 (*Characterisation of waste – sampling of waste materials – Framework for the preparation and application of a sampling plan*) had not yet been published by CEN. Therefore sampling of waste was dealt with the wording "a sampling plan shall be developed according to part 1 of the sampling standard currently developed by CEN". EN 14889 finally was approved by CEN on 28 October 2005.

The principles or basic rules outlined in this European Standard provide a framework that can be used to:

- Produce standardized sampling plans for use in regular or routine circumstances (elaboration of derived standards dedicated to well defined sampling scenarios).
- Incorporate the specific sampling requirements of European and national legislation.
- Design and develop a sampling plan for use on a case by case basis.

There may be a need to take more than one sample to meet all requirements of the testing programme. Ultimately the sampling plan provides the sampler with detailed instructions how sampling should be carried out. By developing a sampling plan the responsible person has to reconsider and analyse the case specific sampling problem, which leads to better results and to reduce the probability of incorrect sampling.

The sampling plan determines how waste samples should be taken, to get a representative sample and also to determine the testing methodology (or total content leaching test) that should be performed. With repeated testing a sampling plan ensures that the sampling will be performed the same way every time. The sampling plan is a valuable system for quality control. If you have not taken a representative sample, the analysis itself has limited or no value. At worst the result is directly misleading.

To develop a sampling plan is a multi-step process with repeated contacts between stakeholders until a desired level of detail is achieved. A draft of the sampling plan is reviewed by stakeholders so that unrealistic objectives, inaccuracies, etc. can be corrected. A basic principle is that a sampling plan is made specifically for a particular sampling problem, not generally for a particular type of waste.

Important tasks to be defined in a sampling plan can for instance be as follows:

- The purpose of the test (basic characterization or other).
- The defined population and sub-populations to be sampled to achieve the testing purpose.
- The scope of characterization.
- The degree of accuracy for the selected sampling strategy (statistical accuracy & precision).

Sampling activities

Landfill Directive - Article 11

(b) […] 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

Council Decision 2003/33/EC – Annex 1.3 On-site verification

Upon delivery, samples shall be taken periodically. The samples taken shall be kept after acceptance of the waste for a period that will be determined by the Member State (not less than one month; see Article 11(b) of the Landfill Directive.

4.2. Description

Acceptance criteria for landfills

According to European legislation there are limit values for the following six types of landfills:

Table 1: Types of landfills

Type of landfill	Limit values
Landfill for **inert waste**	*(leaching values and total content)* The definition in the directive for **inert waste is: 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. This kind of waste may be admitted without testing at a landfill for inert waste. In case of suspicion of contamination, testing should be applied. If there is doubt that the waste fulfils the definition of inert waste testing must be applied, the methods listed under section 3 of the directive shall be applied. Examples of inert waste are: glass, soil and stones and concrete.
Landfill for **non-hazardous waste without testing**	*(municipal waste)* The definition for **municipal waste** is recalled in art.3 of the Waste Framework Directive 2008/98: " *(a) mixed waste and separately collected waste from households, including paper and cardboard, glass, metals, plastics, bio-waste, wood, textiles, packaging, waste electrical and electronic equipment, waste batteries and accumulators, and bulky waste, including mattresses and furniture;* *(b) mixed waste and separately collected waste from other sources, where such waste is similar in nature and composition to waste from households*".. The wastes may not be admitted if they have not been subjected to prior treatment according to Article 6(a) of the Landfill Directive, or if they are contaminated to an extent which increases the risk associated with the waste sufficiently to justify their disposal in other facilities.
Landfill for **non-hazardous waste in same cell as stable non-reactive hazardous waste** (leaching values and total content)	According to art. 3 of the Directive 2008/98/EC, hazardous waste means waste which displays one or more of the hazardous properties listed in Annex III of that directive. According to the Council Decision 2003/33, Stable, non-reactive means that the leaching behaviour of the waste will not change adversely in the long-term, under landfill design conditions or foreseeable accidents: — in the waste alone (for example, by biodegradation), — under the impact of long-term ambient conditions (for example, water, air, temperature, mechanical constraints), — by the impact of other wastes (including waste products such as leachate and gas).
Landfill for **non-hazardous gypsum waste without testing**	*(in special cells without biodegradable waste)* In the Council Decision is written that non-hazardous gypsum-based materials should be disposed of only in landfills for non-

	hazardous waste in cells where no biodegradable waste is accepted. The limit values in paragraph 2.3.2 and 2.3.1 should apply to waste landfilled together with gypsum-based material. The reason for these limit values for TOC and DOC is that they are parameters that give an indication of the biodegradability of the waste.
Landfill for **non-hazardous that accepts hazardous waste** (leaching values and other criteria)	Hazardous waste that may be accepted at landfills of non-hazardous waste must be stable and non-reactive which means that the leaching behaviour of the waste will not change adversely on the long-term, under landfill design conditions or foreseeable accidents. In the Council Decision limit values are given for granular hazardous waste and asbestos waste (2.3.1, 2.3.2 and 2.3.3)
Landfill for **hazardous waste** (leaching values and other criteria)	In paragraph 2.4.1 and 2.4.2 limit values are given for granular waste at landfills for hazardous waste.

The testing methods to be applied when testing different kind of wastes are:

- Leaching limit values for parameters which are given in the decision depending on the kind of waste and kind of landfill.
- Leaching limit values for total content of organic parameters.

The website of the European commission contains the report "*Assessing legal compliance with and implementation of the waste acceptance criteria and procedures*[5]" giving an overview on how Member States have implemented the decision of the Commission.

The report's findings are that the relevant testing methods as mentioned in the WAC decision have been implemented by the Member States covered in that report. Some Member States in addition to CEN standards have their own national standards. Many of these additional standards cover sampling, sampling plan, PAH, PCB, TDS, leaching tests with different pH levels and water analyses (testing).

[5] https://ec.europa.eu/environment/pdf/waste/landfill/report_wac.pdf

In the following figure included in the WAC Decision the steps to follow when landfilling a waste are shown:

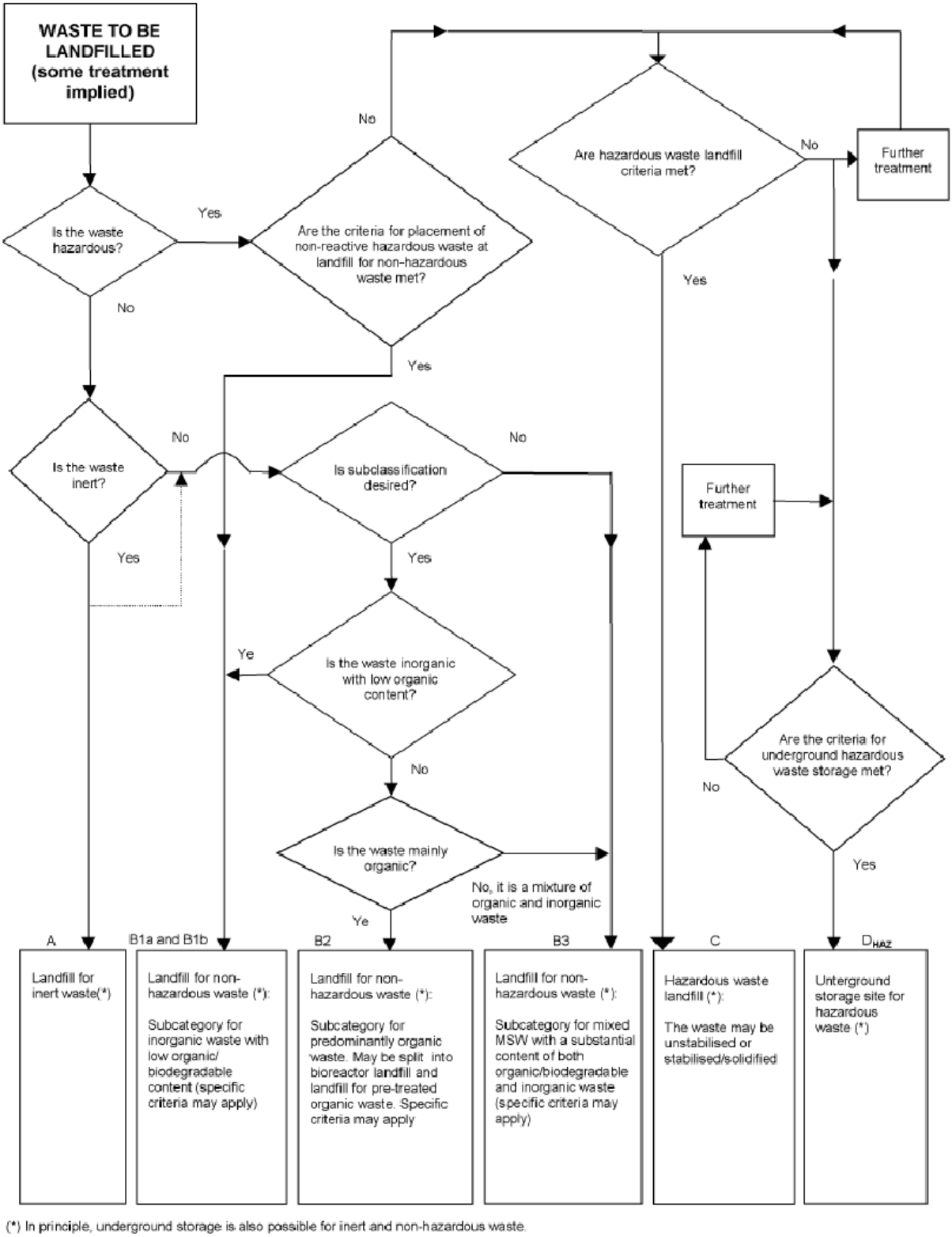

Figure 4: Landfilling options

According to the Council Decision (and Landfill Directive) a procedure must be followed before the waste can be considered for landfilling. This procedure demands that the waste has to be described and in many cases also sampled and analyzed.

The procedure involves three steps (see below):

- Basic characterization (1.1)
- Compliance testing (1.2)
- On-site verification (1.3)

Figure 5: Waste acceptance at weighbridge at landfills in Slovenia and Romania

Table 2: Waste acceptance steps

1.1 Basic characterisation.	Basic characterisation is the first step in the acceptance procedure and constitutes a full characterisation of the waste by gathering all the necessary information for safe disposal of the waste in the long term. Basic characterisation is **required for each type of waste.** Depending on the kind of waste (and if this needs to be tested) 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.
1.2. Compliance testing.	This constitutes periodic 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. When waste has been deemed acceptable for a landfill type on the basis of a basic characterisation pursuant to section 1 in the Council decision**, the waste shall subsequently be subject to compliance testing to determine if it complies with the results of the basic characterisation and the relevant acceptance criteria** as laid down in section 2 in the Council Decision. The function of compliance testing is periodically to check regularly arising waste streams. The relevant parameters to be tested are determined in the basic characterisation. Parameters should be related to basic characterisation information; only a check on critical parameters (key variables), as determined in the basic characterisation, is necessary. The check has to show that the waste meets the limit values for the critical parameters. The tests used for compliance testing shall be one or more of those used in the basic characterisation. The testing shall consist at least of a batch leaching test (depending on the kind of waste). For this purpose the methods listed under section 3 shall be used. Wastes that are exempted from the testing requirements for basic characterisation in section 1.1.4(a) and section 1.1.4(c) in the Council decision are also exempt from compliance testing. They will however, need checking for compliance with basic characterisation

	information other than testing. Compliance testing shall be carried out at least once a year and the operator must in any event, ensure that compliance testing is carried out in the scope and frequency determined by the basic characterisation.
1.3. On-site verification	This constitutes rapid checking 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. **Each load of waste delivered to a landfill shall be visually inspected before and after unloading. The required documentation shall be checked.** For waste deposited by the waste producer at a landfill in his control, this verification may be made at the point of dispatch. The waste may be accepted at the landfill, if it is the same as that which has been subjected to basic characterisation and compliance testing and which is described in the accompanying documents. If this is not the case, the waste must not be accepted. Member States shall determine the testing requirements for on-site verification, including where appropriate rapid test methods. Upon delivery, samples shall be taken periodically. The samples taken shall be kept after acceptance of the waste for a period that will be determined by the Member State (not less than one month; see Article 11(b) of the Landfill Directive.

4.3. Best practice

Acceptance criteria for landfills

In this paragraph best practice examples are given that were seen during the IMPEL project and in other studies that have been issued by the European Commission.

Landfilling of waste has been continuously reduced in recent years. In 2022, 5.0 tonnes of waste were generated per EU inhabitant; 40.8% of waste were recycled and 30.2% landfilled in the EU:

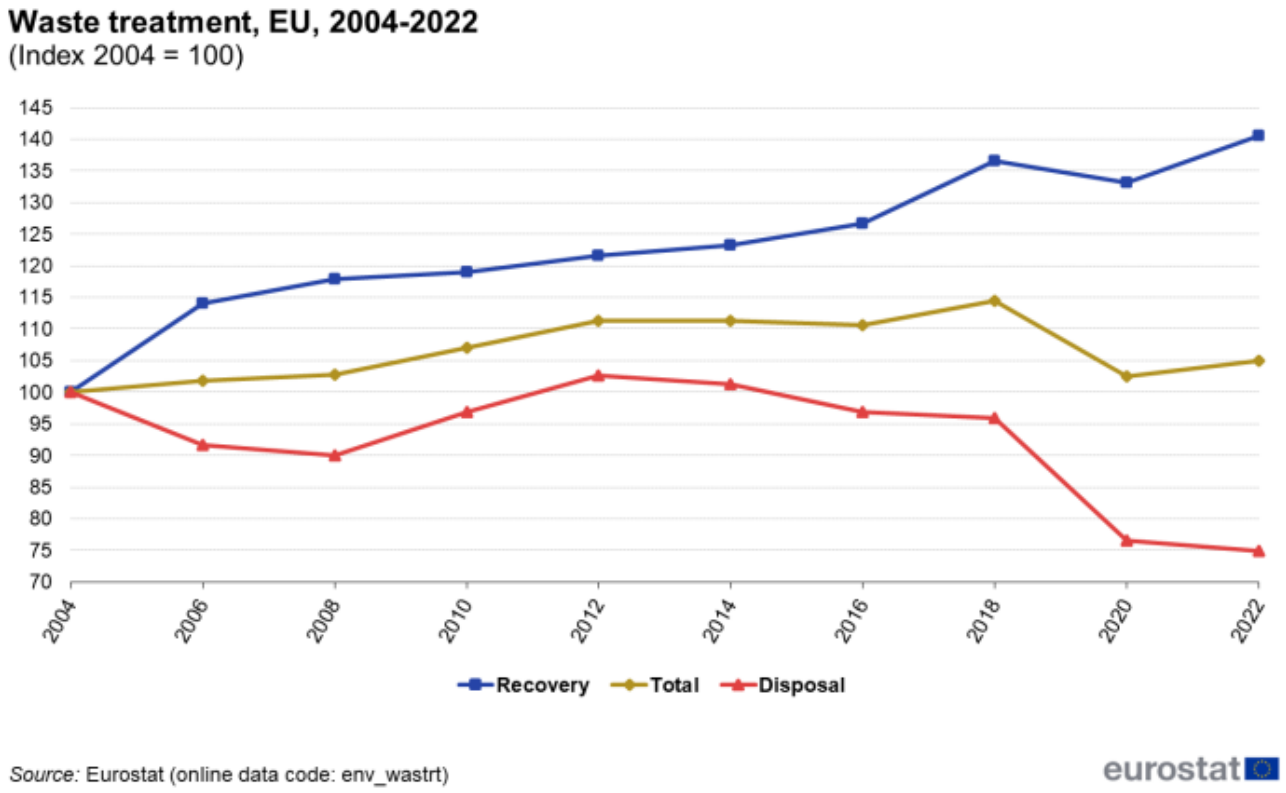

Figure 6: Waste statistics (source Eurostat)

Along the project it has been seen that in most of the Member States that have been visited (with the exception of Italy and Czech Republic), basic characterisation and compliance testing are both performed by the landfill operator. An exception is also Austria where this is done by an external qualified and certified expert on behalf of the waste owner or the landfill operator.

Compliance testing is requested when the waste is 'regularly generated', which means the waste is of consistent quality and generated by the same process.

For compliance testing you only need to assess the waste against a limited number of parameters. Based on the basic characterisation, identify the main parameters of the waste to understand its variability. You can then sample and test the waste against those parameters.

When compliance testing is performed by the operator, the analysis is intended to be a further check in the waste characterisation procedure.

In the report "*Assessing legal compliance with and implementation of the waste acceptance criteria and procedures by the EU-15*" in which the following Member States were examined: Austria, Belgium, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Spain, Sweden and UK, the following best practices are given from the Member States:

Best practice for on-site verification of the waste:

- Routine on-site sampling of each batch of hazardous waste delivered at a landfill including a quick test for all substances before landfilling (e.g. FR).
- Mandatory automated check for radioactivity of all waste loads delivered (e.g. FR).
- Monthly on-site testing of mixed non-hazardous waste (e.g. DK).

Best practice for leaching limit values:

- Specific limit values for parameters (heavy metals) to be tested (BE - Flanders).

- The same criteria and test methods as for the same type of granular waste after the monolithic waste was crushed (e.g. UK Northern Ireland, SE, FI, DE, DK).
- Limit values have to be met before the stabilizing process (AT, DE).
- Specific provisions for sampling, maturation and leaching test (64 days) as well as specific national leaching limit values are set in the legislation for stabilized hazardous inorganic waste (NL).
- Definition of maturation time (e.g. FR, DE).
- Definition of pH (4 and 11) and size of particle (<10 mm) before the leaching test (DE).
- Additional limit values such as electrical conductivity and certain pH level to be met by monolithic waste (UK England/Wales, UK Scotland).

Best practice for asbestos waste:

- Additional limit values for the disposal of asbestos waste are set (e.g. content of asbestos waste, bulk density, relative density, release index, thickness of the top cover - IT).
- The legislation in England and Wales gives the notion “suitable asbestos waste” a broader meaning in terms of “suitable materials”.
- National legislation defines specific requirements to accept asbestos waste at class C landfills (e.g. sealed double big bags, only in cells where it is entombed into stabilized/solidified waste).

Waste classification

Having performed several on-site inspections, the project group eventually found that there is a significant need for a more detailed description of waste classification. Correct waste classification is needed to verify that a certain kind of waste is correctly landfilled, therefore waste classification is seen as the most crucial part of the waste acceptance process.

In the Commission Decision on the European List of Waste (COM 2000/532/EC) there are rules on how to select a waste code (EWC). It follows a chapter wise structure. A code is chosen according to the following procedural steps (see figure below):

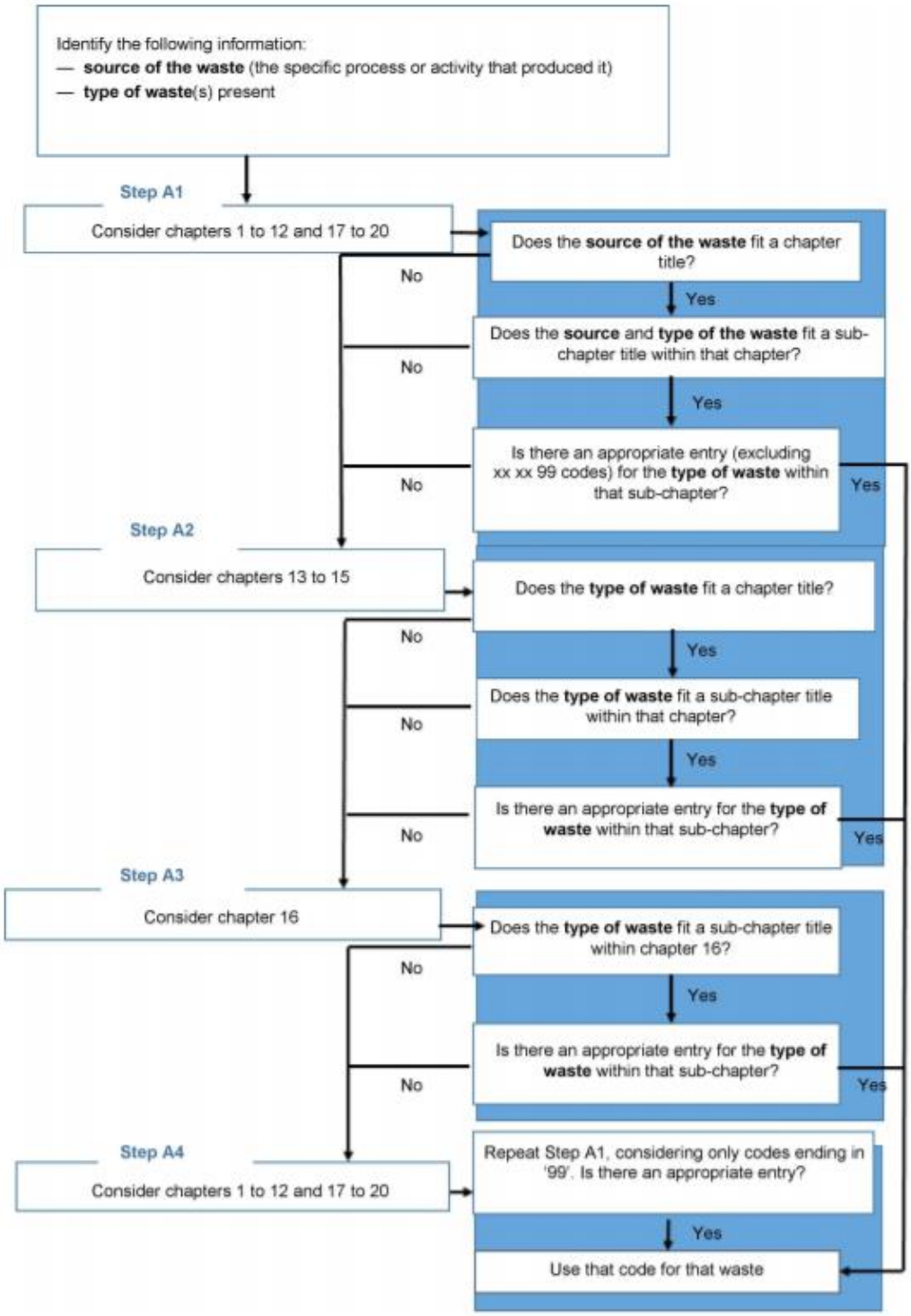

Figure 7: Choose a correct waste code (Source: Commission notice on technical guidance on the classification of waste 2018/C 124/01)

The "*Commission notice on technical guidance on the classification of waste (2018/C 124/01)"* provides clarifications and guidance to national authorities, including local authorities, and businesses (e. g. for permitting issues) on the correct interpretation and application of the relevant EU legislation regarding the classification of waste, namely identification of hazardous properties, assessing if the waste has a hazardous property and, ultimately, classifying the waste as hazardous or non-hazardous.

Annex III to the Waste Framework Directive was amended as concerns hazardous property HP 14 'Ecotoxic' by Council Regulation (EU) 2017/997. Therefore, the assessment of HP 14 should be done as follow:

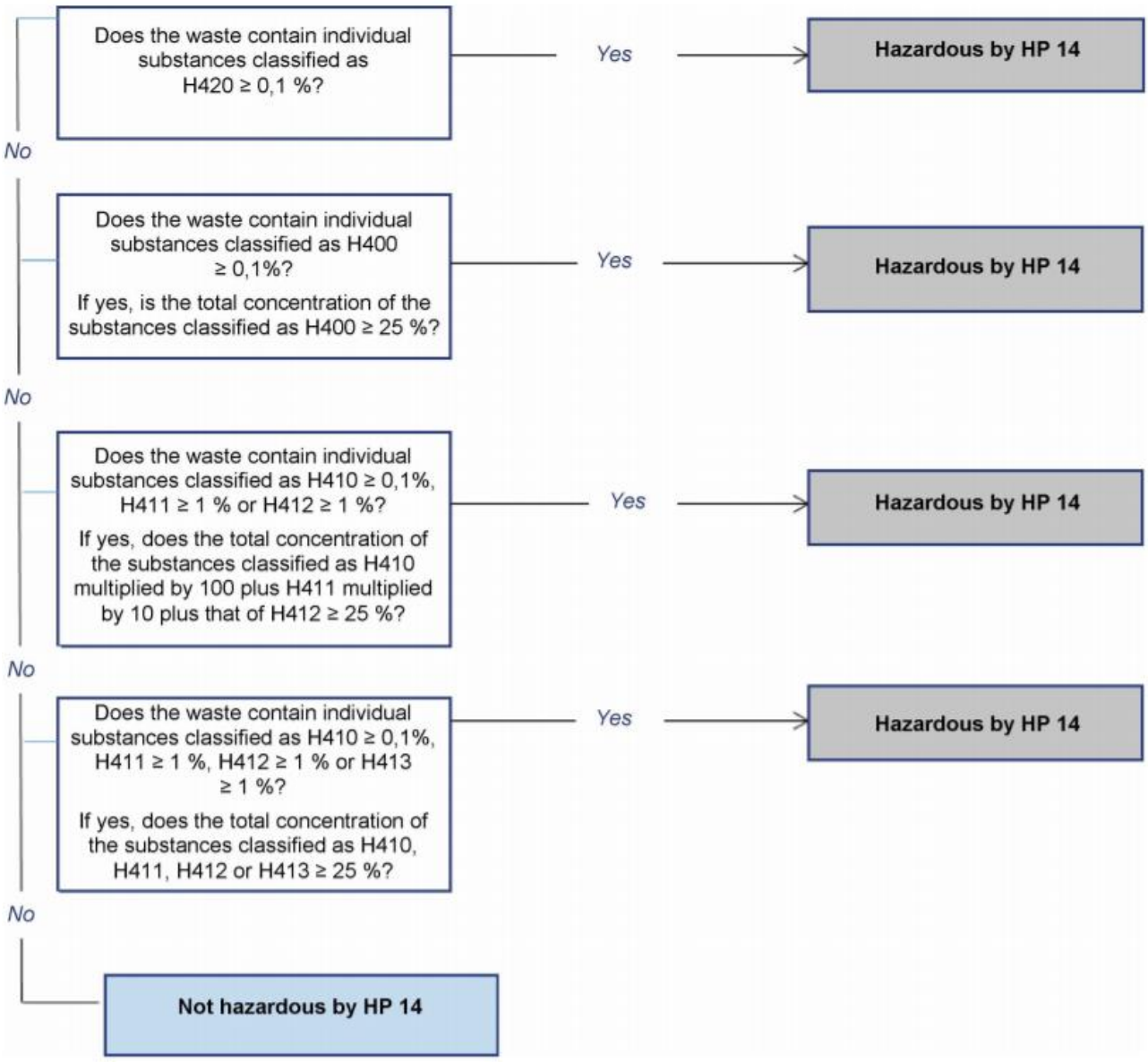

Figure 8: Flow chart for the assessment of HP 14 (Source: Commission notice on technical guidance on the classification of waste 2018/C 124/01)

Sampling of waste

A sampling plan should be developed in accordance with Standard EN 14899:2006 *"Characterisation of waste – sampling of waste materials*". This European Standard specifies the procedural steps to be taken in the preparation and application of a Sampling Plan. The Sampling Plan describes the method of collection of the laboratory sample necessary for meeting the objective of the testing programme.

The number of samples that you need to test depends on the size of the batch of waste and whether the batch is homogeneous or heterogeneous. Homogenous means the waste generally contains the same or similar components. Heterogeneous means the waste generally contains a wide range of different components.

From your basic characterization, if you do not expect the waste to be contaminated above any WAC leaching limit value, you can apply the sampling frequencies in the following level 1 characterization table:

Amount of waste (tonnes)	Homogeneous (number of samples)	Heterogeneous and new wastes (number of samples)
Less than 100 t	2	5
100 to 500 t	3	8
500 to 1,000 t	5	14
1,000 to 10,000 t	11	22
plus per additional 10,000 t	+5 (pro rata)	+10 (pro rata)

Figure 9: Minimum laboratory sample frequency (Source: Gov UK - https://www.gov.uk/guidance/dispose-of-waste-to-landfill#sampling-frequency)

After several on-site inspections, the project group eventually found that there is a significant need for a more detailed look into the way sampling is done with sampling being the most crucial part of the waste acceptance process. A practical sampling demonstration was performed during a site visit (joint inspection) in Austria (AT).

According to the Austrian national legislation, sampling is an obligation for the waste owner and has to be performed prior to the waste transport to a landfill. Only in special cases the sampling part of the waste acceptance procedure is performed on-site at the landfill (at an intermediate storage facility).

Figure 10: Waste sampling demonstration at Lower Austrian landfill

To demonstrate waste sampling according to Austrian legislation an approximately 90-tonne heap of diesel fuel contaminated and already excavated soil was examined. Basic characterization of this kind of waste heaps had to be performed according to Austrian Standard (OeNORM) S2127 which also covers sampling from solid waste from containers and transport vehicles.

The preface of Austrian Standard S2127 states that "*by using this standard the requirements of EN 14899 are fulfilled*". S2127 gives reference to various other national technical standards (based on

EN standards, as EN 903, EN 12457-4, EN 12506, EN 12879 and many more) as well as some ISO & DIN regulation.

Based on the waste owner's basic information ("Waste information for the external certified expert /laboratory"; a form included in Annex A.2 for excavated soil material) a sampling plan was developed by an independent expert /laboratory (on behalf of the landfill operator).

Core data included total waste mass, population size, number of populations, number of qualified samples, number of increments, expected waste code and expected landfill (quality) class.

Sampling was performed under supervision of the visiting IMPEL inspectors. An excavator (grab dredger) was used to split the waste heap into 2 parts (populations) and the material prepared for taking the sampling of the calculated amount of increments.

Sampling was performed by an external qualified & certified expert (accredited laboratory) and a sampling record was completed. Date and time of sampling, weather conditions, actual number of qualified samples, mass of qualified samples, number of increments per qualified sample, colour and odour of the waste, estimated particle size, material consistency and grade of homogeneity and the likelihood of any potential hazardous properties according to Directive 2008/98/EC on waste (Waste Framework Directive), Annex III were documented. A detailed description and characterisation of the qualified samples (mapping, location, depth) was also added. Further information regarding the collection of replicate samples, packaging and transport of the samples taken, GPS data and photographic documentation was provided.

Figure 11: Waste samples taken and prepared for transport to laboratory

Preparations for sampling activities comprise the following activities:

- **Qualification for sampling:** waste sampling should be done only by certified /accredited persons /institutions (to be seen as best practice).
- **Compiling all necessary information** on the waste to be sampled ("waste information"):
  - Waste owner (name, address, e-mail, phone contact; contact person), project name and waste identification code.
  - Origin of waste (production process, waste collection, treatment procedures or other).
  - Short description of the process the waste is originating from.
  - Relevant input materials (especially when waste already was processed/treated).

- Waste code - according to EWC or national standard.
- Amount of waste – total mass (m^3), density (tons/m^3), total waste mass (tons); type and form of material.
- Description of waste storage (still in-situ, roof protected, open air storage, encased, waste heap storage, container storage, waste stored since when).
- Description of waste quality – material not contaminated / obviously contaminated / contaminations to be expected / contamination very likely? Describe contamination (known/obvious/likely).
- Background information e.g. previous investigations or analysis. Other information on contaminations of waste in question or of input materials.
- Document signed / approved by waste owner.

- **Preparing a sampling plan:**

  Depending on the structure/quality (homogenous/heterogeneous) and location of the waste (in-situ sampling of soil material, sampling from waste heaps or containers /transport vehicles etc.) a sampling plan has to be made or depending on national legislation, sampling plans for certain sampling scenarios have to be applied.

  Compile all relevant data, such as:

  - Waste information to be provided by waste owner (see above).
  - Sampling plan author (name, address, phone, e-mail).
  - Involved parties (waste owner / independent expert/laboratory).
  - Objectives/purpose of assessment (waste going to landfill/recovery/other destination/purpose).
  - Determine level of testing required.
  - Constituents to be tested.
  - Health & safety precautions.
  - Technical goals (define populations /subpopulations.
  - Variability (spatial /temporal); Scale of sampling.
  - Practical Instructions (statistical approach, sampling approach & pattern, sampling place & points; equipment needed.
  - Sample details (individual /composite; number of samples / increments; composite sample size; primary samples combined into composite samples).
  - Requirements for sample reduction & on-site determination.
  - Packaging, preservation, storage & transport requirements (sample labelling, preservation methods.
  - Analytical laboratory (company details, contact name).

- **Preparing a sampling protocol:**
  - Sampling plan number / Identification /reference number /code.
  - Waste owner / contact person.
  - Laboratory / qualified expert on sampling: contact person (name, address, phone, e-mail).
  - Involved parties /other persons attending (name, address).
  - Sampling location (address, GPS data if available, site details).

- Data of sampling (data, hour, period).
- Weather conditions (sunny /dry /rainfall /snow /temperature /wind).
- Waste mass (tons).
- Qualified samples (number of); number of increments per qualified sample.
- Mass of qualified sample (kg).
- Alternate / replicate samples taken (y/n; if yes who did it?).
- Way of sampling (conveyor belt moving/not moving; falling stream; from waste heap/ stockpile; soil: borehole, trench or other; machinery used).
- Description & characteristics of qualified samples (location).
- Transport of samples (open /closed container; cooled /not cooled).
- Contaminations apparent (odour / visible contaminations / gas/ other irregularities).
- Waste color.
- Odour.
- Particle size (mm) & consistency (solid/dry/wet/sludge/dusty/powdery etc.).
- Homogeneity of waste (colour/odour/particle size).
- Hazardous properties to be expected (y/n)? If yes, which?
- Deviations from Sampling Plan (waste mass; number of populations; number of qualified samples; other ?).
- Additional relevant information.
- Mapping (GPS or other geodetically data) and photographic documentation of location & waste (particle size /color/ homogeneity).
- Date & signature of sampling expert (prepared by / prepared for).

- **Preparing all necessary technical equipment:** check availability of sampling instruments & machinery (excavator, grab dredger, soil anger, trier, thief, sampling scoop or other).

Keeping the samples

According to the Landfill Directive (Article 11) and Council Decision 2003/33/EC (Annex 1.3 On-site verification), representative samples have to be taken in order to implement Annex II, point 3, level 3. The samples taken shall be kept after acceptance of the waste for a period that will be determined by the Member State (not less than one month.

Suggestion for permitting authority

Keeping a sample of the waste for a defined period allows the inspection authority to take it for further analysis to assess the compliance to the acceptance criteria. The quantity of the sample should allow such analysis. Further indications can be given about the frequency and the waste object of the sampling.

The following provision is suggested to permitting authorities:
"*Upon delivery to the landfill, samples are taken on an annual basis. Samples must be taken on loads entering the landfill for each producer and for each EER code. In case of same EER code, same producer and a different production site/batch, samples should be taken from each site/production lot.*
Samples weighing 2 kg must be taken in suitable containers, and identified by a special mark labeling showing:
- *EER waste code*
- *Producer*
- *Date of collection*
- *Reference to the waste transportation form*

- *Reference to the Basic characterization.*

The samples must be taken in accordance with the EN standard by suitably trained personnel, in order to ensure its representativeness; they must be accompanied by the relevant sampling plan and stored at the landfill facility and kept at the disposal of the Inspection Authority for a period of not less than two months.
For the three main waste contributors, in quantitative terms, the frequency will be quarterly and the samples must be stored for a period of 3 months.
The operator must take care to distribute the sampling over the whole period of the year, both for the purpose of one better management of storage spaces and to allow the presence of samples available to the Inspection Authority control at any time of the year.
The annual self-monitoring report must contain a summary of the samples taken in relation to each EER code and producer entering the landfill".

4.4. Preparing an Inspection (desk study)

Acceptance criteria for landfills

Before going on inspection it should be very clear what the subject of the inspection will be. Information needed for an inspection on the subject of waste acceptance at a landfill is:

- The permit which is issued to the landfill.
- Which legislation is relevant for the inspection beside the permit (are there general binding rules which have to be taken into account?).
- The monitoring and other reports the landfill operator had to provide to the Competent Authority. Are these relevant for this subject?
- What kind of landfill is it? Which waste streams are most critical for contamination?
- If possible, look at the waste streams the landfill has received the last 6 months prior to your inspection.
- Select four different kinds of waste streams and with the help of the checklist perform your inspection (see checklist example).

Waste classification

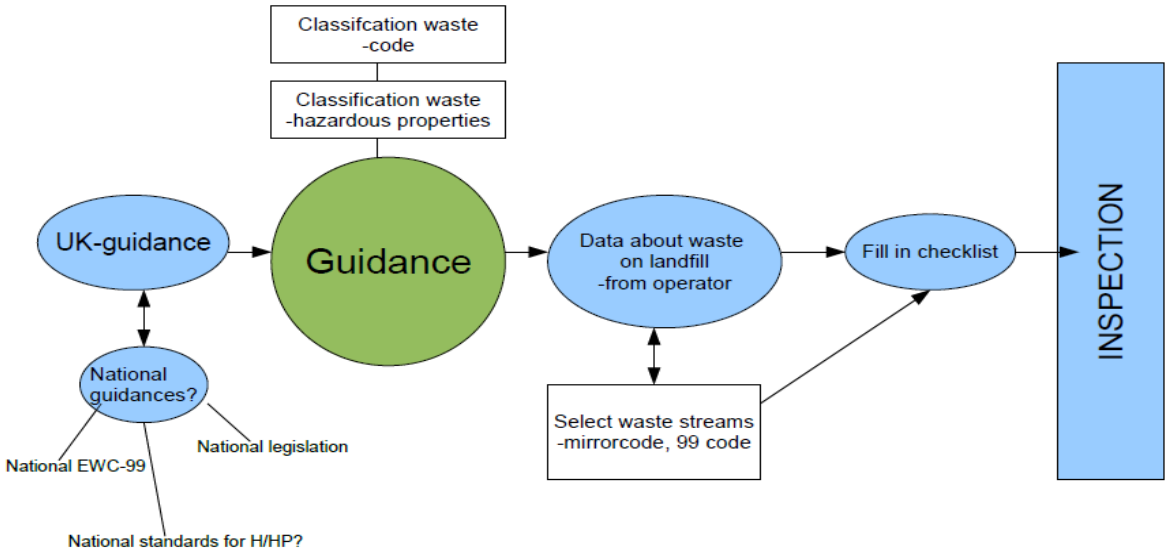

Figure 12: How to prepare an inspection to check the correct "classification of waste".

The desk study activities includes:

- Reading the annual report which usually contains waste statistics.

- Reading the EU-guidance and, if available, national guidance. There can be more specified national legislation, national waste codes and standards for assessment of hazardous properties, so check if this is the case in your country.
- Ask the landfill operator to send you a list of all the wastes that are landfilled. Ask for a list from the last 12 months. Ask for: name of the waste, waste code, waste producer and amount of waste.
- Select 4 different waste streams that will be checked. For example: a mixed waste, a waste with a mirror-code, a waste that ends with 99, a stable-non reactive waste and the most common waste that are landfilled.
- Fill in the checklist (see Annex 3).

Sampling of waste

Preparing an inspection comprises as a main issue to define the scope of "what to inspect":

- Check Landfill documentation: find out particular/typical types of waste (waste streams) deposited at the site for an in-depth assessment (waste where a higher degree of sampling /a more sophisticated sampling normally is necessary or expected);
- Check the sampling plan of the respective waste (deposited at the landfill) well ahead of a site visit in order to verify the correct use of sampling methodology according to national / EU legislation (e.g. EN 14899 et. al);
- Prepare site visit protocol (according to Checklist see Annex 2);

Prepare technical equipment for site visit.

4.5. On-site Inspection

Acceptance criteria for landfills

Use the checklist for the on-site inspection. Take pictures when you suspect that something is not according to the permit or national binding rules. When there is a discussion on the kind of waste that may be accepted and/or has been accepted, take samples (if your Agency has this capability, otherwise ask to an external company).

Waste classification

- Ask to have access to the basic characterization (BC) for the waste stream(s) chosen.
- Check if there is information on the risk of hazardous properties, and fill in the checklist (see below).
- If waste is mirror-code or ends with "99" and there is a risk of hazardous properties or properties that are not known or documented, then the landfill operator must not accept the waste for landfilling before the waste producer have supplied data about the properties of the waste.

1. CLASSIFICATION OF WASTE										
Chosen wastes										
Waste code	Name of waste	Absolute Hazardous or non-hazardous?		Mirror-code?	Code that ends with -99?	Risk of hazardous properties? Properties is:				In compliance?
		Yes Hazardous	Yes non-hazardous	Yes	Yes	not documented	not known	documented	no risk of hazardous properties	If waste is absolute hazardous or non-hazardous go to part for WASTE ACCEPTANCE CRITERIA FOR LANDFILLS AND PRE-TREATMENT OF WASTE If waste is mirrorcode or ends with 99, and there is a risk of hazardous properties and they have been documented, go to part for WASTE ACCEPTANCE CRITERIA FOR LANDFILLS AND PRE-TREATMENT OF WASTE If waste is mirrorcode or ends with 99, and there is a risk of hazardous properties or properties is not known or documented, then the landfill operator should not accept the waste for landfilling before the wasteproducer have supplemented data about the properties of the waste.
120199	Blasting material	-	-	-	yes		yes			
200307	Fly ash (oil)	yes						yes		
170504	Soil from contaminated site			yes		yes				
190805	Sluge waste watertreatment		yes						yes	

Figure 13: Example of checklist to be used for waste classification (see Annex 3)

Sampling of waste

All the checks listed are necessary to complete the checklist.

- Ask to see all documents regarding waste accepted at the landfill, in particular sampling plans & sampling records (protocols and affiliated data).

  The following parts of a sampling plan could be verified:

  - The population size representing a sample and how the waste is produced (as a heap/stockpile, from a falling stream or from excavation.
  - Number of sub-samples (increments) depending on homogeneity or heterogeneity of the waste.
  - Size of the sample(s) taken (a minimum amount /mass of a sample as defined in national /international standards).
  - Who has conducted the sampling? (qualification of certified /accredited person /institution).

Checking these parts should enable an inspector to find hints of the probability that the sampling was conducted in a satisfactory manner or something is not correct.

- Check sampling plans against national and EU legislation requirements (statistical approach, number of samples taken, correct use of forms, standards etc.).
- Ask for an on-site demonstration to check if sampling is done properly.
- Check storage of replicate samples (storage facility, correct labelling, correct handling, sufficient quantity).
- Check sampling equipment and other technical facilities (if available and sampling is done at the landfill).

Figure 14: Replicate storage facility at Lower Austrian landfill

4.6. Existing guidelines

Acceptance criteria for landfills

- UK Government "Dispose of waste to landfill"[6]
- SEPA Guidance note on landfill[7]
- German Ordinance for Landfill and long -term storage

Waste classification

- UK Government "Technical Guidance WM3: Waste Classification"[8]
- Commission notice on technical guidance on the classification of waste[9]
- Italian SNPA (EPA's network) Guidance on waste classification[10]

Sampling of waste

It has already been indicated that a sampling plan should be developed in accordance with standard EN 14899:2006. Beside this standard, among the existing guidance available, five national documents have been identified containing good pieces of advice to create a suitable sampling plan:

A. *Nordtest Method (NT ENVIR 004, of Nordic Countries, approved 1996-05; published by NORDTEST, Finland)*

6 https://www.gov.uk/guidance/dispose-of-waste-to-landfill#treat-waste-for-landfill

7 https://www.sepa.org.uk/regulations/waste/landfill/

8 https://www.gov.uk/government/publications/waste-classification-technical-guidance

9 https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=uriserv:OJ.C_.2018.124.01.0001.01.ENG&toc=OJ:C:2018:124:TOC

10 https://www.snpambiente.it/wp-content/uploads/2021/07/Delibera-105-2021-LLGG-Classificazione-rifiuti.pdf

A well established test methodology on sampling of solid waste and particulate materials. The scope of this guidance covers the probabilistic approach of (random) sampling of solid residues (e.g. ashes, slags and similar residues) up to 80mm particle size based on classical statistics.

Importance is laid on the technical differences when sampling has to be performed at different locations (from conveyor belt stopping/moving, falling stream or at a stationary position (e.g. containers, vehicles or from a stockpile).

NT ENVIR 004 also gives an overview of fundamental statistics (distribution models, sample variance) as well as strategies (probabilistic, random – simple, stratified, systematic) for collection of samples. A 2-page example of a sampling plan is provided and furthermore examples of sampling equipment. The following table gives an example how to define the number of primary samples:

Table 3: Minimum number of primary samples to be collected from a lot/sampling unit containing 30 tons or less

Designation	Heterogeneity	n. of primary samples
A	Homogeneous solid residues, such as coal fly ash sampled from a falling stream	5
B	Heterogeneous solid residues, such as bottom ash from mass burn incinerators sampled from a falling stream	7
C	Very heterogeneous or stratified solid residues, such as residues in wagons, vehicles, stockpiles	10

B. Waste Sampling – Appendix D of Waste Classification: Guidance on the classification and assessment of waste (Technical Guidance WM2 - 1st edition 2015; published by UK Environment Agency.)

A 5-step methodology based on current European and British standards (e.g. EN 14889). Starting with Preparatory Steps such as identifying parties, objectives, technical goals, background information, level of testing plus health & safety precautions) technical goals from the objective define population to be sampled. After assessing variability and defining the scale practical sampling instructions are determined (statistical approach, sampling approach, type, number & size of samples and finally a sampling technique chosen. The procedure is finished with the documentation of a sampling plan.

Special interest is laid on Step 3 - the determination of practical instructions in order to choose the right statistical and sampling approach plus the number & sample size (pp D11 – D25). A 2-page sampling plan form is provided for documentation purposes.

C. Austrian Standards OeNORM S 2126 (published 01-12-2010 by Austrian Standards Institute) and S 2127 (published 01-11-2011)

Both technical standards were issued to set the benchmark for waste sampling and eventually became part of Austrian legislation (landfill ordinance) defining the minimum requirements for sampling. The approach is to have a simple but yet sufficient system to ensure that any kind of waste possible can be tested in a way that the average content of pollutants and the leaching behaviour is determined and the waste finally can be assigned to a certain landfill class (quality class).

Both standards include several Annexes for documenting the waste information by the waste owner (to the independent external qualified expert/laboratory), a sampling plan form, sampling record form and other information on randomized sampling and technical advice to determine mass, volume and density of waste.

D. German PN 98 guideline for sampling waste - LAGA PN 98 [11]

This guidance sets the current benchmark for sampling waste in Germany and contains a.o.:

- Sampling of solid waste and deposits.
- Sampling strategy and plan.
- Performing sampling
- Preparation of the single, composite or aggregate sample for laboratory analysis
- Preservation, labeling, packaging, shipping.

The PN 98, which can only be used for solid waste, is supplemented by the guide for an application (Handlungshilfe) published in 2019.

E. Italian UNI 10802:2023

This technical standard describes:

- methods for manual sampling of waste in relation to their different physical states;
- procedures for size reduction of the waste samples collected in the field to facilitate transport to the laboratory;
- documentation for the traceability of sampling operations.

It also provides practical examples of waste sampling plans.

The forms, prepared for each type of waste, are accompanied by photos, description of the sampling strategy and the procedure for sample reduction, equipment, particle size range, number and mass of increments.

[11] https://www.laga-online.de/documents/m32_laga_pn98_1503993280.pdf

5. STABLE NON REACTIVE WASTE

5.1. Legal requirements and definitions

Stable non–reactive wastes are defined in article 6 of the Council Directive 1999/31/EC and in the Council Decision n. 2003/33/EC of 19 December 2002. This category of hazardous wastes can be disposed in landfills for non hazardous waste. The definition is reported in Box 1:

BOX 1 Definitions

Council Directive 1999/31/EC (LFD)

Article 6: Waste to be accepted in the different classes of landfill

[…]

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

(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 hazardous wastes shall not be deposited in cells destined for biodegradable non-hazardous waste.

COUNCIL DECISION 2003/33/EC OF 19 DECEMBER 2002

ANNEX: Criteria and procedures for the acceptance of waste at landfills - 2. Waste acceptance criteria

[…]

2.3. Criteria for hazardous waste acceptable at landfills for non-hazardous waste pursuant to Article 6(c)(iii).

Stable, non-reactive means that the leaching behaviour of the waste will not change adversely in the long-term, under landfill design conditions or foreseeable accidents:

- in the waste alone (for example, by biodegradation),
- under the impact of long-term ambient conditions (for example, water, air, temperature, mechanical constraints),
- by the impact of other wastes (including waste products such as leachate and gas).

2.3.1. Leaching limit values

The following leaching limit values apply to granular hazardous waste acceptable at landfills for non-hazardous waste, calculated at L/S = 2 and 10 l/kg for total release and directly expressed in mg/l for C0 (the first eluate of percolation test at L/S = 0,1 l/kg). Granular wastes include all wastes that are not monolithic. Member States shall determine which of the test methods and corresponding limit values should be used.

[*the leaching test limit values are skipped*]

2.3.2. Other criteria

In addition to the leaching limit values under section 2.3.1, granular wastes must meet the following additional criteria:

Parameter	Value
TOC (total organic carbon)	5 % (*)
pH	Minimum 6
ANC (acid neutralisation capacity)	Must be evaluated

(*) If this value is not achieved, a higher limit value maybe admitted by the competent authority, provided that the DOC value of 800 mg/kg is achieved at L/S = 10 l/kg, either at the material's own pH or at a pH value between 7,5 and 8,0.

Member States must set criteria to ensure that the waste will have sufficient physical stability and bearing capacity. Member States shall set criteria to ensure that hazardous monolithic wastes are stable and non-reactive before acceptance in landfills for non-hazardous waste.

The provisions of the Landfill Directive and the Council Decision have the aim of guaranteeing that stable non-reactive waste are separately disposed of or eventually co-disposed with low reactive non hazardous waste. The focus of the Decision is to set limits in order to minimise the effects caused by the biodegradability of wastes (TOC limit) and acid conditions of the leachate produced by the waste (pH value) and to guarantee a sufficient acid neutralisation capacity of the hazardous stable non-reactive waste (ANC to be evaluated), in order to buffer the acidic pH conditions, which may allow an increase of metal solubility and release.

A study developed by BIPRO on behalf of the EU Commission in 2009 (*Assessing legal compliance with and implementation of the waste acceptance criteria and procedures by the EU-15*) assessed the implementation of such (and other) provisions in the national legislations (Box 2).

BOX 2: stable non-reactive waste provisions implementation

Non-reactivity of stabilised waste

The majority of Member States request in the national legislation a non-reactivity as stipulated in the WAC Decision. More specific criteria for determination of non-reactivity; however, are generally not set.

TOC, pH and ANC

[…] The other is the necessity to determine ANC given the lack of a related limit value.

Observed deficits:

[…]

In some countries the (e.g. NL, DE, BE Wallonia avant project) the obligation to determine the ANC is not implemented; In this context, it is important to note that the German translation of the WAC Decision does not require such an analysis for class B but only for class C, and that ANC is contained as parameter in the list of substances to be analysed in Annex 3(2) "acceptance criteria".

In Flanders the regional legislation (VLAREM) states that "*the obligation to determine the ANC (acid neutralizing capacity) is adopted. It is specified that the buffer capacity of the waste must be sufficient so that the limit values for leaching also remain the same in contact with infiltrating precipitation*".

Physical stability and bearing capacity

Only some Member States have implemented criteria for the physical stability and bearing capacity of the waste whereas this section could be identified as one of the most frequent lack of implementation.

The UK SEPA Technical Guidance Note "*The Disposal in Landfills for Non-Hazardous Waste of Stable, Non-Reactive Hazardous Wastes*" states that stable, non-reactive hazardous wastes could potentially include a range of monolithic solidified wastes (wastes in large blocky forms such as those that have been mixed with cement or PFA) or granular solid wastes produced by a variety of treatment plants (such as filter cakes and treated fly ash); a blanket classification of such waste types and the processes through which they have been treated is not possible and each waste stream will require to be individually assessed and a risk assessment conducted in light of the assessment and the intended landfill destination.

According to the Italian Guideline "*Technical criteria to establish when waste treatment is not necessary prior to landfilling*[12]", for stable non-reactive waste it is intended for those wastes subjected to preliminary treatments which are therefore identified by the EWC codes 19 and, in particular, by the codes 1903 "stabilized / solidified waste" and 1904 "vitrified waste and vitrification wastes".

As far as the physical stability and bearing capacity is concerned, Italian law states that stable-non reactive waste should be subjected to appropriate geotechnical tests to demonstrate adequate physical stability and load capacity. For the assessment, Italian law refers to the WAC acceptance

12 https://www.isprambiente.gov.it/it/pubblicazioni/manuali-e-linee-guida/criteri-tecnici-per-stabilire-quando-il-trattamento-non-e2019-necessario-ai-fini-dello-smaltimento-dei-rifiuti-in-discarica-ai-sensi-dell2019art.-48-della-l.28-dicembre-2015-n.221

criteria of the United Kingdom Environmental Protection Agency and to operating procedures and criteria to be defined by a national decree (not yet issued).

In the GOV.UK document "*Landfill operators: environmental permits*"[13], it is stated that, where you dispose of SNRHW (or asbestos or high sulphate bearing wastes), you must normally provide evidence that the base, side walls and cap will meet the standards required by the Landfill Directive, annex 1. The design must be based on a risk assessment; where the risk assessment requires the collection of leachate and landfill gas, the separate cell must normally have its own leachate and landfill gas collection and extraction systems.

Leachate and landfill gas from separate and adjacent cells containing non-hazardous waste may be treated in the same treatment plant. The operator must assess the risk posed by using the same treatment plant.

The separation must prevent contact between the different types of waste, waste products, including leachate and landfill gas; the operator has to show that the separation will remain effective and that the waste will remain undisturbed.

Separation of cells can be achieved either by:

- construction of dedicated separating structures; or
- managed placement of wastes to segregate waste inputs.

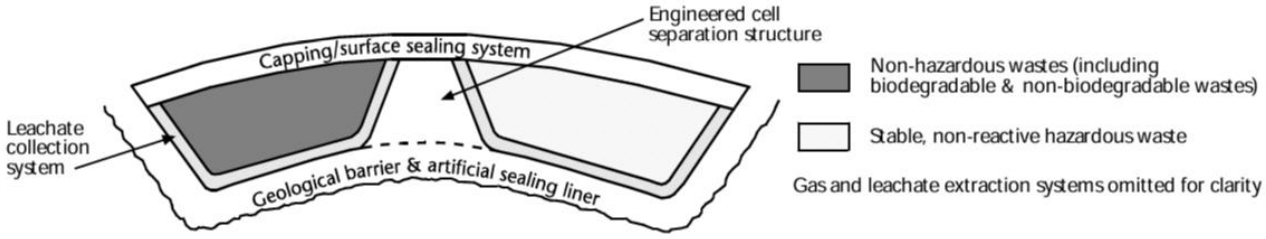

Figure 15: Schematic illustration of engineered separation of cells

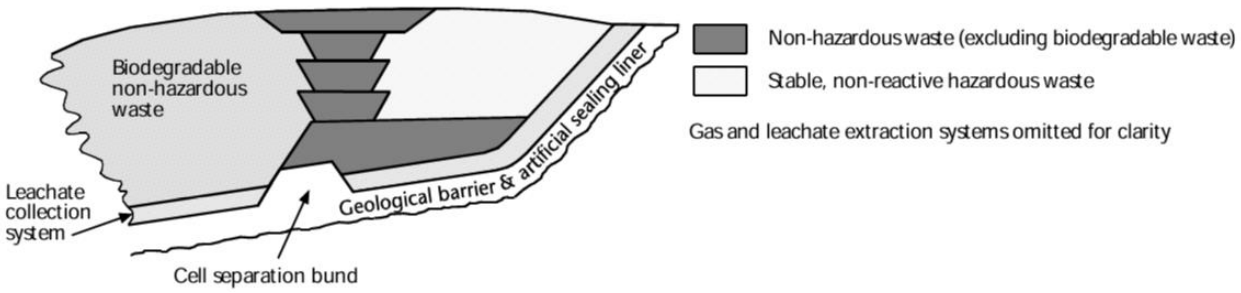

Figure 16: Schematic illustration of managed cell separation by segregation of waste placement

The UK SEPA above mentioned Guidance states that there should be no interaction between the wastes in the separate cells and their respective management systems according to the following principles:

- no direct physical contact between stable, non-reactive hazardous wastes and biodegradable non-hazardous waste; - there should be no contact between waste products within the landfill cells (including leachate or gas);
- separate leachate collection and extraction systems (but not necessarily separate treatment and discharge systems);

[13] https://www.gov.uk/guidance/landfill-operators-environmental-permits/accept-the-right-waste

- where landfill gas collection and extraction systems are required they should be separate (but not necessarily separate utilization or flaring);
- operation of cells for stable, non-reactive hazardous wastes must not compromise the continuing management of cells for biodegradable non hazardous wastes.

Therefore, the EU and the national provisions state general conditions on how hazardous stable non-reactive wastes have to be disposed in landfills for non hazardous waste, in order to ensure sufficient mechanical stability and to avoid chemical transformations due to waste behaviour within the landfill body.

No specific definition or guidance is given to explain how to assess the stability and no reactivity of hazardous waste, except of setting a maximum TOC value, a minimum pH value, leaching limits and stating the waste leachate behaviour shouldn't change in the long term.

5.2. The Acid Neutralization Capacity (ANC)

The meaning and the use of the parameter ANC is described in Box 3.

BOX 3. What's ANC?

ANC is a "multi-parameter", i.e. it is a curve with several values of acid concentration [mol H^{+}/kg dm] added to a waste leachate in order to achieve different pH steps in the range between 2 and 12. This test could be performed using CEN/TS 14429 (the last review is the one of 2015) or CEN/TS 14997 standard methods.

ANC is a parameter often used in the soil sciences to assess the buffering capacities of a soil to overcome to acid rains (Sverdrup, Sweden). It was utilized from Dutch researchers (ECN, Hans van der Sloot, Van Zoemeren etc.) to assess the behaviour of wastes within the landfill body, particularly to evaluate the wastes buffer capacity again the acid leachate in order to limit the metals leaching from wastes to the bottom of the landfill. Danish researchers (Thomas Astrup, Ole Hjelmar for example) studied this "multi-parameter" particularly in the case of bottom and fly ashes to be disposed of in landfill.

Thomas Astrup (Professor of the Technical University of Denmark) carried out research studies on that, discriminating between "**static**" and "**dynamic**" ANC. The first one is that one determined using the above cited CEN/TS methods and evaluates the current buffer capacity of a waste; the second one is determined using the results of the same tests, in order to feed a calculating model, that evaluates how the buffering (acid neutralisation) capacity of the waste is lost in the long term by dissolution of its stable non-reactive minerals, which encapsulate for example metals. The model considers the meteorological parameters (annual infiltration rate) and the waste disposing conditions within the landfill body (height of the waste layer, bulk density of the waste) in order to calculate how many years are necessary to change the own waste pH value due to the dissolution of its buffering minerals. The result is given by a graph, which represents the pH development versus time (years). A stable non reactive waste should show limited change of the own pH value in a long time (long term behaviour).

In the northern countries of Europe most of the waste is incinerated before landfilling and therefore the principal wastes to be disposed are bottom and fly ashes, bioashes etc (see, Hjelmar et al., 2009 *Treatment methods for waste to be land*filled, Norden). The chemical characteristics of this kind of waste are well known and the ANC is evaluated before landfill construction. In other Countries (like Italy) different industrial hazardous waste categories are landfilled without a pre-burning step, possibly after chemical-physical pre-treatments (stabilisation, immobilisation treatments). Consequently, it is not possible to evaluate ANC within the project permitting procedure. The local EPA needs to apply a specific methodology in order to assess this parameter during on site inspection.

There aren't any specific methodologies to evaluate ANC yet. The Norden Council published a technical report with a general approach to the problem. Flanders landfill rule 38/95 (Vlarem) states that the buffer capacity (ANC) has to maintain the leachate values according to the rain infiltration rate in the landfill body. The Landfill UK regulations states the evaluation of the ANC at three pH steps, i.e. at the waste natural pH value, at the leachate pH value and at pH = 6.

The main question is to define criteria to evaluate ANC in basic characterisation and compliance testing in landfill. Veneto Region EPA (ARPAV) – Regional Observatory of Wastes (Italy) studied this item between 2012 and 2016 and proposed to the Italian Institute for Environmental Research and National EPA (ISPRA) a specific evaluation methodology, based on a literature review and experimental tests. The latter were applied to different hazardous waste categories applied to three landfills and by Veneto Region EPA laboratory. Such methodology may be used for routinely ANC evaluation.

BOX 4 Proposal of a methodology to evaluate ANC test results

The main conclusions of the report developed by Veneto Region EPA (ARPAV) about ANC assessment were the following:

a) The first step is the evaluation of the "static ANC", i.e., obtained from CEN/TS 14429/2006 or 14997/2007 methods. Special attention has to be put to the value of ANC at pH value of 4.5 (ANC4.5). This value, on the analogy of total alkalinity measured in water samples (at a pH level of 4.5), has to be considered as the maximum buffering capacity of the waste before landfilling and includes the buffering capacities of hydroxides, carbonates, high reactive silicates and other compounds. This value could be compared with the maximum buffering capacity of calcite mineral (i.e. 20 mol H+/kg). The data of waste buffering capacities founded in literature and experimental data, until now collected, are below this value. High ANC4.5 values indicates a high buffering capacity and then a high resistance to change the own pH value (natural pH) again the effect of more acid leachate elution. This means also that the leaching test results at the own pH won't significantly change with time due to the effect of leachate acidification: the waste could be defined as stable non reactive complying the definition set out from Decision 33/2013.

b) The second step is to evaluate "dynamic ANC". This one could be used to better investigate waste with a low static ANC. It could be done applying the test proposed by Prof.Astrup et. al (Technical University of Denmark). This test evaluate the weathering of waste ANC with time. Astrup proposed a simple model to evaluate long term waste pH evolution due to the weathering of minerals involved in neutralization capacity. The result of the test is a graph with the pH of the waste vs time. If the pH value in the long term doesn't diverge from the own pH value it could be assumed that the waste is stable non reactive in compliance with definition of Decision 33/2003, i.e. the " the leaching behaviour of the waste will not change39/95 adversely in the long-term". The long term pH value could be compared with the typical leachate pH value (7-8) of an inorganic landfill and with the maximum pH value (6) accepted for stable non reactive hazardous waste.

c) A leaching test (using CEN/TS 14429/2006 o 14997/2007 methods) at the critical pH value (6), achieved in the long term as results from Astrup test, could finally establish if the leaching behaviour changes at such pH different from the own pH.In fact it could be possible that specific pollutants (as heavy metals) are included in an amorphous structure and don't leach from the matrix.

A methodology to evaluate ANC could be the following:

1) Evaluation of static ANC4.5 (obtained from CEN/TS 14429/2006 o 14997/2007 methods). If the value is greater than 3,5 mol H+/kg dm the hazardous waste could be considered as stable non reactive. This value is proposed by Wahlströmet al., 2009 as a high neutralization capacity in relationship with literature values. The result obtained by Veneto Region EPA study show ANC4.5 values in the range 0,1 – 14,2 mol H+/kg.s.s, so the value of 3,5 mol H+/kg ss was considered as a minimum acceptable value;

2) If the static ANC4.5 is below 3,5 mol H+/kg dm, the dynamic ANC (Astrup test) has to be carried out and if the result of the simplified model shows that the pH value in the long term (5.000 years as suggested by Astrup) is greater then 6 the waste could be assessed as stable non reactive;

3) If the result of Astrup test is negative (a pH below 6 is achieved in the long term) a leaching test at a pH value of 6 has to be carried out and the results has to comply with WAC.

6. WASTE CONTAINING ASBESTOS

Asbestos is the name for a group of naturally occurring, fine-fibred minerals (silicates). There are three main types of asbestos; chrysolite (white asbestos), amosite (brown asbestos) and crocidolite (blue asbestos). Since asbestos is extraordinarily resistant to heat and to a large extent to chemicals, it was used to manufacture a wide variety of products. There is an increased risk of asbestos fibres being released, especially from products with a weak fibre bond or broken asbestos cement products. Inhaled asbestos fibres can cause asbestosis and are carcinogenic.

Basically, a distinction must be made between:

- Products and waste with a solid fibre bond. These are in particular asbestos cement products, which were used on a large scale in the construction sector as flat and profiled boards or as pipes, but also other products such as brake linings. Waste containing solid bond asbestos- generally has a bulk density of more than 1400 kg/m^3 when bound with cement.
- Products and waste with weak fibre bond. These include above all sprayed asbestos and other products with weakly bonded asbestos fibres such as lightweight boards, asbestos boards, sealing cords, which were used for fire protection, sound insulation and heat and moisture protection. Waste containing weakly bound asbestos- usually has a bulk density below 1000 kg/m^3.

Asbestos-containing wastes are materials, substances, preparations and products that contain asbestos or to which asbestos fibres adhere (asbestos-contaminated wastes).

Waste containing asbestos arises:

- In particular during demolition, renovation or maintenance work.
- During the disposal of products containing asbestos from households, trade and industry.

The handling of these activities is defined in the national regulations of the MS.

6.1. Legal requirement

According to Regulation (EC) No 1272/2008 (CLP Regulation) Annex VI, asbestos is classified as a carcinogen (category 1A carcinogen, substances known to be carcinogenic to humans, with hazard statement H350). The absorption of asbestos fibres from the air by inhalation is decisive for health effects. With a few exceptions, products containing asbestos may no longer be placed on the market in EU under Regulation (EC) 1907/2006 (REACH Regulation) and also special regulation in Member States.

Paragraph 2.3.3 of the Council Decision of 19 December 2002 establishes the criteria for asbestos waste (hazardous waste) to be accepted at landfills for non-hazardous waste. Article 6(c)(iii) of Council Directive 1999/31/EC on the landfill of waste specifies those wastes which may be accepted in a non-hazardous landfill and allows for certain hazardous wastes to be deposited provided they are stable and non-reactive.

BOX 5 Asbestos waste

Construction materials containing asbestos and other suitable asbestos waste may be landfilled at landfills for non-hazardous waste in accordance with Article 6(c)(iii) of the Landfill Directive without testing. For landfills receiving construction materials containing asbestos and other suitable asbestos waste the following requirements must be fulfilled:

- the waste contains no other hazardous substances than bound asbestos, including fibers bound by a binding agent or packed in plastic,
- the landfill accepts only construction material containing asbestos and other suitable asbestos waste. These wastes may also be landfilled in a separate cell of a landfill for non-hazardous waste, if the cell is sufficiently self-contained,
- in order to avoid dispersion of fibres, the zone of deposit is covered daily and before each compacting operation with appropriate material and, if the waste is not packed, it is regularly sprinkled,
- a final top cover is put on the landfill/cell in order to avoid the dispersion of fibres,
- no works are carried out on the landfill/cell that could lead to a release of fibres (e.g. drilling of holes),
- after closure a plan is kept of the location of the landfill/cell indicating that asbestos wastes have been deposited,
- appropriate measures are taken to limit the possible uses of the land after closure of the landfill in order to avoid human contact with the waste.

For landfills receiving only construction material containing asbestos, the requirements set out in Annex I, point 3.2 and 3.3 of the Landfill Directive can be reduced, if the above requirements are fulfilled.

6.2. Management/handling

Belgium

1. General conditions in asbestos control.

All necessary measures are taken to ensure that:

- During the transportation, the loading, and unloading of waste materials which contain asbestos fibres or asbestos dust, these fibres and dust cannot be released into the air and no liquids are discharged which may contain asbestos fibres.
- Where waste materials containing asbestos fibres or dust are landfilled at sites licensed for this purpose, such waste is so treated, packaged or covered, taking local conditions into account, that the release of asbestos particles into the environment is prevented.
- Activities related to working with asbestos-containing products may cause no significant environmental pollution due to asbestos fibres or dust.
- The demolition of buildings, structures and establishments containing asbestos and the removal therefrom of asbestos or materials containing asbestos, involving the release of asbestos fibres or dust do not cause the release of asbestos into the environment.

2. At landfills

Each waste load arriving at a landfill is visually inspected before and after unloading. The required documentation is also checked. For waste deposited by the producer of the waste at a landfill under his/her management, this verification may take place at the point of sending.

The waste may be accepted at the landfill if it is the same waste as subjected to the basic characterisation and compliance tests and is described in the associated documents. If this condition is not met, it is not permissible for the waste to be accepted.

In Flanders, a distinction is made between friable and non-friable asbestos with regard to the manner in which they need to be disposed of. It became mandatory to double-bag non-friable

asbestos, label and dispose it, while friable asbestos has to be cemented before disposal. In short, this implies that the asbestos containing waste gets crushed and mixed with cement and other additives resulting in 1m³ blocks in which the asbestos fibres are captured.

3. Criteria for asbestos waste, acceptable at landfills for non hazardous waste

Building material that contains asbestos and other suitable asbestos waste may be deposited without tests on landfills for non-hazardous waste materials when it is in accordance with the provisions of Article 6, c), iii) of EC directive 1999/31/EC paraphrased as follows:

- They are stable, non-reactive hazardous waste materials, with leaching behaviour equivalent to those of the acceptance criteria at landfills for non-hazardous waste materials.
- They must meet the relevant acceptance criteria.
- These hazardous waste materials are not deposited in cells destined for biodegradable non-hazardous waste materials.

For landfills receiving asbestos-containing building material and other suitable asbestos waste, the following requirements must be met:

- The waste contains no other hazardous substances than bound asbestos, including asbestos fibres bound by a binding material or packaged in plastic.
- The landfill only accepts asbestos-containing building material and other suitable asbestos waste; the waste may also be deposited in a separate cell of a landfill for non-hazardous waste materials if the cell is sufficiently isolated.
- In order to avoid the dispersion of fibres, the landfill zone is covered daily and before each compacting operation with appropriate material and, if the waste is not packed, it is regularly irrigated.
- Finally, a top cover is put completely over the landfill/cell in order to avoid the dispersion of fibres.
- No works are carried out on the landfill/cell that can lead to a release of fibres (e.g. drilling holes).
- After closure a plan is kept of the location of the landfill/cell indicating that asbestos waste has been deposited.
- Appropriate measures are taken to limit the possible uses of the location after closure of the landfill in order to avoid human contact with the waste.

4. Criteria related to asbestos waste acceptance

Hazardous asbestos-containing waste materials do not always meet the acceptance criteria for landfills for not hazardous waste, e.g.:

- Waste materials containing free asbestos fibres such as spray asbestos, asbestos insulating material, asbestos dust including soil materials and other waste materials polluted by unbound asbestos fibres in concentrations > 0.1% by weight or in which asbestos flakes are clearly observable.
- Packaging waste and plastic waste polluted with asbestos.
- Waste that cannot be shredded, such as metal parts coated or clad with asbestos or an asbestos-containing material. Waste that cannot be shredded is understood as material where in pursuance of the Best Available Techniques the asbestos part cannot or only with great difficulties be separated from the carrier material.

- Asbestos-containing waste materials also include: waste materials wholly or partly consisting of ceramic fibres with similar carcinogenic properties.

Waste materials consisting of asbestos-containing building materials in which asbestos fibres in bound form exist, can be deposited on a landfills for hazardous waste materials (category 1) if the following conditions are met:

- Waste materials containing free asbestos fibres or asbestos dust may only be deposited if they have been treated in such a way that no asbestos particles can escape into the environment. To that end the waste materials are cemented so that the asbestos fibres present are encased in a matrix. The asbestos waste must be spread evenly within the cemented material. The asbestos flakes or debris present in the cemented material may not exceed 1 cm in size. The cemented material is packed in dust-proof plastic packaging with the necessary asbestos labelling.
- Packaging and plastic waste polluted with asbestos is compressed to a density of at least 400 kg/m³. The compressed material is packed in dust-proof plastic packaging with the necessary asbestos labelling.
- Non-shreddable material that is covered or coated with asbestos or asbestos-containing material is packed in double-walled dust-proof plastic packaging with the necessary asbestos labelling.
- Asbestos-containing waste materials are treated and deposited in such a way that no asbestos fibres or asbestos dust can escape into the air and no liquids are lost that might contain asbestos fibres or asbestos dust. The pre-treatments required with a view to depositing in a landfill are carried out in an appropriate establishment.
- The evaluation methodology for asbestos-containing waste and the fibre exemption test are included in the Belgian Guideline "*Asbest in gerecycleerde granulaten en bodem*" (CMA/2/II/C.1).

As a limitation to what's mentioned above, at category 1 landfill sites only those waste materials may be accepted which are explicitly permitted in the environmental licence for the operation of the classified establishment or activity.

5. *In practice*

Most landfills for asbestos containing waste have procedures with concrete measures they take to comply with the legal provisions. These procedures are included in the work plan. The environmental inspection division checks on several critical points in the chain of the asbestos containing waste if the legal conditions are met.

For a landfill that means:

- Is the asbestos containing waste well packed (double-walled dust-proof plastic packaging)?
- Are only those wastes accepted for which a permit has been issued?
- Is there a visual inspection before unloading?
- Although the use of an endoscope is not mandatory, this technique allows you to do a visual inspection without having to open the well closed packaging of asbestos containing waste.
- Is the asbestos containing waste deposited in a separate cell, well isolated from the rest?
- Is the asbestos containing waste daily covered? Is regular irrigation provided?
- Is the location of the asbestos containing waste well known? Even after closure?

Germany

Hazardous waste may only be deposited:

- at landfills or landfill sections which fulfill all the requirements for landfill for hazardous waste (German class III) and if the assignment criteria are met, or
- at landfills which meet all the requirements for landfill for mining waste.

In special cases hazardous waste that meets all classification criteria may be deposited in a landfill or a landfill section for household waste (German class II) or in a landfill or a landfill section for inert waste (German class I).

This also applies to waste containing asbestos and waste containing other hazardous mineral fibres, provided that:

- There are no indications that the waste does not comply with the classification criteria for the respective landfill class and
- The waste is deposited in a separate section of a landfill section.

Storage must be protected from the weather and mechanical stresses in suitable and labelled containers so that no asbestos fibres are released. Existing packaging must not be removed. Waste may only be accepted into the warehouse by skilled or competent personnel.

The following packaging in particular should be used:

- Well-sealable woven plastic bags of various sizes (big bags, big plate bags) for firmly bound asbestos-containing waste,
- dust-tight woven plastic bags of various sizes (big bags, big plate bags) for weakly bound asbestos-containing waste
- single-layer PE plastic films with a minimum thickness of 0.4 mm; joints must be overlapped and glued, e.g. with adhesive tape.

This packaging is only suitable for stackable asbestos cement boards. Each stack of panels must be packed individually. It must be ensured that the stacks can be loaded and unloaded properly using suitable lifting gear or machinery.

Existing guidances:

LAGA LänderArbeitsGemeinschaft Abfall	M 23-Implementation Guide for the Disposal of Waste Containing Asbestos (2015)[14] LAGA Merkblatt 23
Federal Republic of Germany	“Landfill ordinance” Ordinance on Landfills and Long-term Storage Facilities 2009/2020[15] “Depoinieverordnung”

Italy

According to the italian legislation, asbestos containing waste can be landfilled in:

a) landfill for hazardous waste, dedicated or equipped with a dedicated cell;

b) landfill for non-hazardous waste, dedicated or equipped with a single-dedicated cell for the waste identified by the European list of waste code 17 06 05*; for other types of waste containing asbestos, provided they are subjected to treatment processes (in accordance with the provisions of Ministerial Decree no. 248 of 29 July 2004) and with values compliant with the following Table, verified at the intervals established by the competent authority.

[14] https://www.laga-online.de/documents/m23_final_juni_2015_2_1517834576.pdf

[15] https://www.gesetze-im-internet.de/depv_2009/DepV.pdf

Asbestos cells must be spaced to allow vehicle access without causing breakage of the asbestos-containing waste. To prevent fiber dispersion, the deposit area must be covered with appropriate material daily and before any compaction operation. If the waste is not packaged, it must be regularly watered. The materials used for daily covering should have a plastic consistency to conform to the shape and volume of the materials to be covered, providing adequate protection against fiber dispersion, with a soil layer of at least 20 cm thick. No activities, such as drilling, that could cause fiber dispersion should be carried out in the landfill or area. A map indicating the location of asbestos-containing waste within the landfill or area must be prepared and maintained.

Treatment is not necessary if the waste originally has characteristics that comply with the table itself:

Table 4: Criteria for admissibility to landfills for non-hazardous waste of treated asbestos-containing waste

Parameter	U.m.	Value
Asbestos content	(% by weight)	<= 30
Relative density	(%)	> 50
Bulk density	(g/cm^3)	>2
Release index		<0.6

Furthermore, disposal procedures and criteria, equipment and personnel protection measures from contamination by asbestos fibers must be respected. Self-monitoring plan should also include analysis of airborne particulate containing asbestos. The analytical techniques of phase contrast optical microscopy must be adopted (MOCF).

UK (SEPA)

SEPA accepts that asbestos waste can be determined to meet the definition and criteria of a stable non-reactive hazardous waste suitable for disposal in a non hazardous landfill provided it is landfilled in a separate, sufficiently self-contained cell.

There should be limited contact of landfill gas and leachate from the biodegradable wastes with the asbestos wastes.

The inspector has to check the following procedures are respected:

- Only waste asbestos and non-hazardous construction materials containing, or contaminated, with asbestos can be accepted in the cell.
- The asbestos must either be rigid asbestos bound by a binding agent or fibrous asbestos. All asbestos wastes shall be packaged where appropriate in accordance with the appropriate approved codes of practice and guidance documents.
- In order to avoid dispersion of fibres, the zone of deposit shall be covered daily with suitable inert material and, if the waste consists of rigid asbestos that is not packed or for any other reason asbestos is not properly contained, it shall be regularly sprinkled. The waste shall be covered immediately to a depth of at least 250mm.
- Final cover should be not less than two metres of suitable material and asbestos waste shall not be within 2 metres of the edge or surface of the landfill after final completion of restoration works. For all these purposes, suitable material should be used, comprising incombustible, granular material free from any objects capable of disrupting the waste or any packing.
- Asbestos waste to be segregated from non hazardous waste by at least 2m of suitable material.
- A final top cover shall be placed on the landfill/cell in order to avoid the dispersion of fibres.

- No works shall be carried out on the landfill/cell that could lead to a release of fibres (e.g. drilling of holes).

7. BIOGAS CONTROL AND ODOURS

7.1. Legal requirements

The Landfill Directive sets regulations about biogas control and reduction measures. Landfill gas means all the gases generated from the landfilled waste.

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.

Further provisions about landfill gas are set in Article 13, Annex I and III of the Landfill Directive:

Article 13: Closure and after-care procedures

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

(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.

Annex I General requirements for all classes of landfills

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 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.

Annex III Control and monitoring procedures in operation and after-care phases

3. Emission data: water, leachate and gas control

Gas monitoring must be representative for each section of the landfill. The frequency of sampling and analysis is listed in the following table:

Table 5: Landfill gas monitoring

	Operating phase	After-care phase
Potential gas emissions and atmospheric pressure (CH_4, CO_2, O_2, H_2S, H_2, etc). These measurements are related mainly to the content of organic material in the waste	**MONTHLY**[16] CH_4, CO_2, O_2, regularly other gasses according to the composition of the waste deposited with a view to reflecting its leachate properties.	**EVERY SIX MONTHS** Efficiency of the gas extraction system must be checked regularly.

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

7.2. Description

The Landfill Directive defines landfill gas as '*all the gases generated from the landfilled waste*'. Landfill gas, therefore includes gaseous emissions arising from all physical, chemical and biological processes occurring within the waste, e.g. microbial production, chemical reactions and direct volatilisation.

Landfill gas is generated in all landfills where organic waste is disposed; it is a natural by-product of the anaerobic biological decomposition of the organic portion of solid waste. Landfill gas consists primarily of Methane (CH_4) and Carbon Dioxide (CO_2), but may contain many other constituents in small quantities, including nitrogen, oxygen, sulphides, disulphides, mercaptans, volatile organic compounds (VOCs), ammonia, hydrogen, carbon monoxide, water vapour, and many other organic gases. By volume, landfill gas typically contains 40% to 60% methane and 40% to 60% carbon dioxide.

Decomposition of waste in a landfill occurs in several distinct phases, related to conditions in the landfill, during which different groups of bacteria break down complex organic substances such as carbohydrates, proteins and lipids into successively simpler compounds.

The primary phases are:

Phase I – Aerobic

Phase II – Anaerobic Non-Methanogenic (Acetogenic)

Phase III – Anaerobic Methanogenic (a non-steady phase)

Phase IV – Anaerobic Methanogenic

Phase V - Aerobic

Figure 17 illustrates the production of gas from a body of waste over time in an idealized manner:

[16] If the evaluation of data indicates that longer intervals are equally effective, they may be adapted.

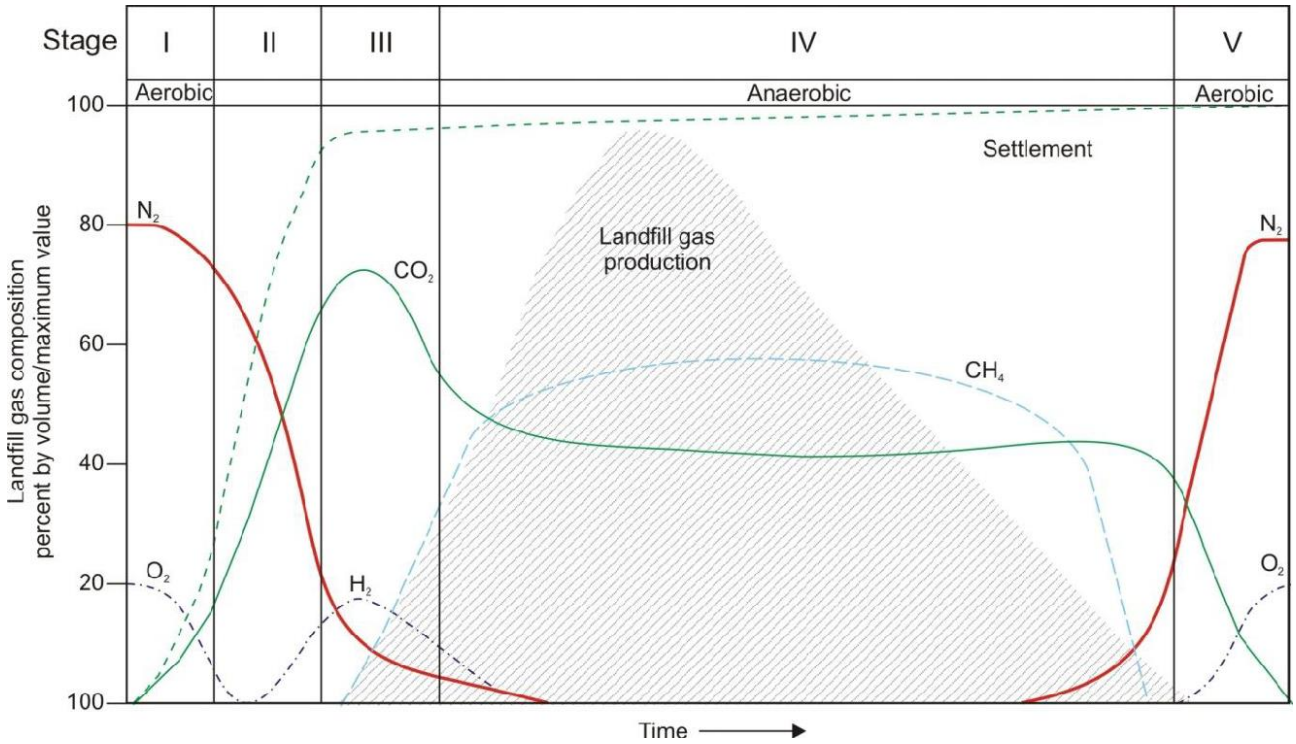

Figure 17: Production of landfill gas during the stages in the lifecycle of a landfill

The rate at which landfill gas is produced is primarily a function of the types of waste involved, e.g: rapidly decomposing food waste versus longer-lasting paper, cardboard or other organic waste. The overall rate of decomposition for all refuse components in a given section of a landfill also is influenced by a variety of other factors, such as moisture content, refuse particle size, site configuration, compaction and pH. Basically, the better the conditions within a landfill are for the anaerobic bacteria the faster the decomposition will take place. This will result in a faster overall landfill gas generation rate build-up.

Landfill gas collection typically begins after a portion of the landfill (known as a “cell”) is closed to additional waste placement. Collection systems can be configured as either vertical wells or horizontal trenches depending on the morphology of the landfill.

7.3. Landfill gas collection

A landfill gas management system has the overall objective to collect all gas produced from the waste and treat it accordingly in order to minimise odours and emissions from the landfill. Specific objectives include the following:

- Minimise the risk of gas migration beyond the boundary of the site.
- Minimise the risk of gas migration into buildings/services on site.
- Minimise the risk of gas explosions.
- Minimise impact on air quality through reduction of greenhouse gas emission.
- Reduction of nuisance potential to the surrounding environment (odour).
- To allow energy recovery where feasible.

A common method of landfill gas collection involves drilling vertical wells in the waste and connecting those wellheads to lateral piping that transports the gas to a collection header using a blower or vacuum induction system. Another type of landfill gas collection system uses horizontal

piping laid in trenches in the waste. Horizontal trench systems are useful in deeper landfills and in areas of active filling. Some collection systems involve a combination of vertical wells and horizontal collectors.

For a secure operation, in both systems the intake of atmospheric air into the landfill body and the gas collecting system must be avoided.

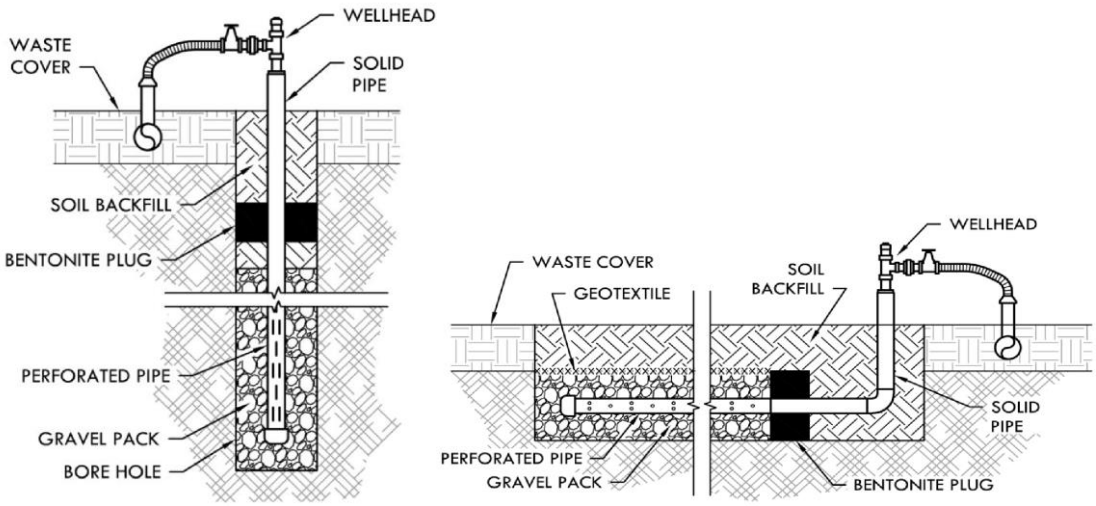

Figure 18: Landfill gas collection system

Figure 19: Landfill gas collection boreholes

7.4. Landfill gas usage

Landfill gas use depends on the minimal quality requirements and flow to guarantee stable performance to keep the system at stable conditions. Landfill gas shall be collected, treated and used from all landfills receiving biodegradable waste unless the landfill operator can prove to the competent authority that it is not necessary to do so.

This proof must be based on a demonstration that the waste types accepted will not produce more than negligible amounts of landfill gas and can be supported by evidence such as from monitoring of the landfill.

According to Italian legislation, energy reuse is subject to a minimum production of truly extractable biogas characterized by a flow rate of not less than 100 Nm^3/h and an expected duration of the flow to the minimum values of not less than 5 years.

BOX 6. Negligible amount of landfill gas

If the competent authority accepts that landfill gas collection is not required, there must be a continuous review process to ensure that landfill gas is not produced in anything other than negligible quantities.

The test for determining whether there are negligible quantities of landfill gas is whether an active methane treatment method can be sustained at the landfill. The quantity of landfill gas considered to be negligible will depend on the methane content and volume of landfill gas that can be sustainably extracted from the waste mass. At landfills where the waste types accepted or the physical attributes of the site mean that there will be very low landfill gas generation then the operator will need to prove that active collection, extraction and treatment of the gas using bio-oxidation techniques or low calorific flaring is unsustainable.

Where the competent authority accepts that landfill gas collection is not required but there are low levels of landfill gas present then passive methane oxidation systems should be considered.

According to the Italian legislation, in case of methane production of less than 0.001 $Nm^3/m^2/h$, it will be possible to make use of biological oxidation in situ, through the use of biofilters or the preparation of adequately designed and sized bio-oxidative covers.

In the landfill gas control hierarchy, gas collection with energy recovery is preferred to enclosed flaring. Though landfill gas can present a hazard to human health and safety and the environment, it can also be a very significant asset in relation to the energy potential of the CH_4 that it contains, and hence its potential for use as a fuel. The primary utilisation modes for landfill gas which have been implemented successfully on a broad-scale is on-site generation of electric power using landfill gas as a fuel within an internal combustion engine, gas turbine or steam turbine generator.

Using landfill gas in an energy recovery system usually requires some treatment of the landfill gas to remove excess moisture, particulates and other impurities. The type and extent of treatment depend on site-specific landfill gas characteristics and the type of energy recovery system employed.

Under the requirements of the Landfill Directive, the operator must assess the potential for utilising landfill gas produced on site and if appropriate make outline proposals for its utilisation. The ability of a facility to produce gas that can be utilised is dependent on:

- The type of waste accepted at the facility (therefore the requirement for energy utilisation principally applies to landfill accepting biodegradable waste).
- The volume of waste and the rate and type of degradation within the facility.
- The size of the facility.

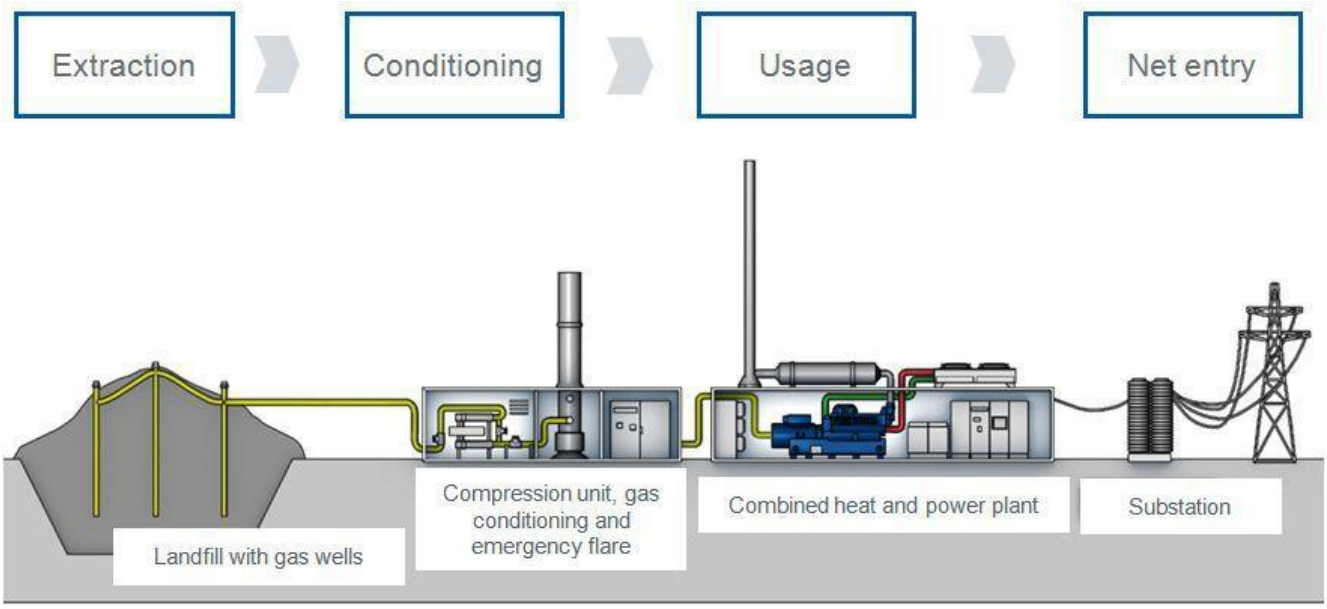

Figure 20: Landfill gas extraction and usage

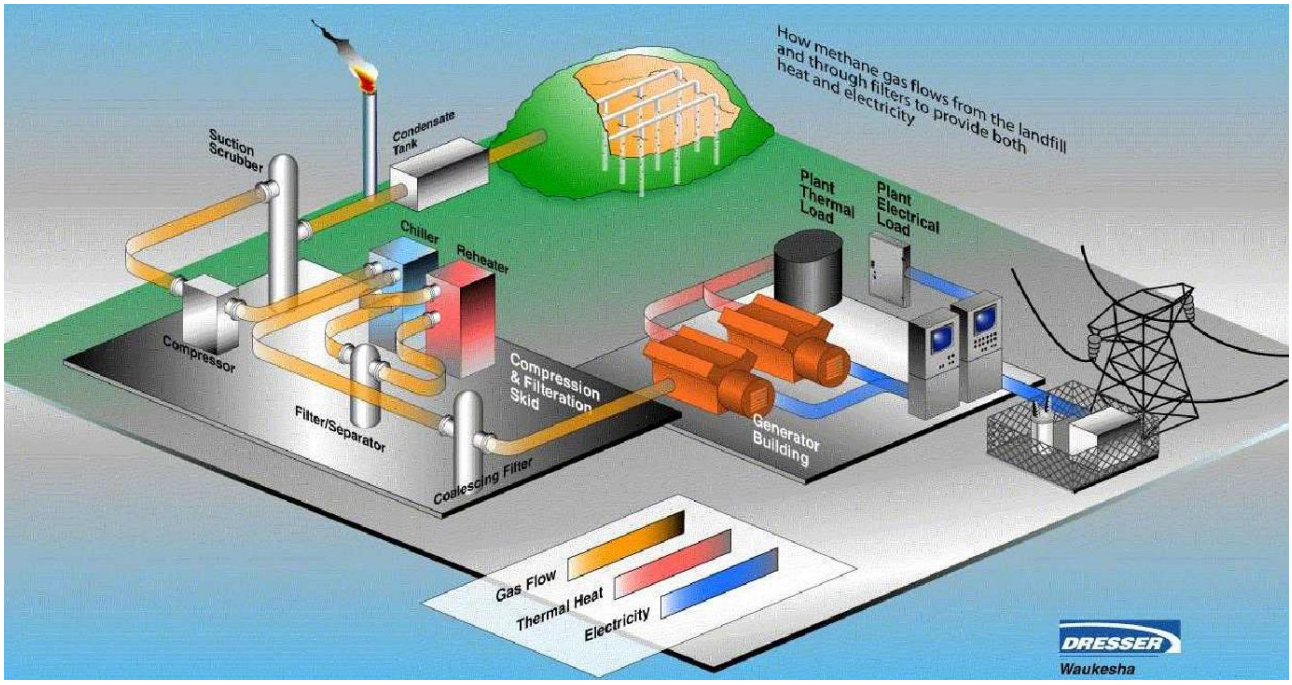

Figure 21: Energy recovery scheme

The first step in developing an energy use project is to determine whether the landfill is likely to produce enough methane to support an energy recovery project.

If it is determined that the energy recovery option is viable, then it is important to estimate the amount of recoverable gas that will be available over time. Softwares as US EPA's LandGEM or GasSim (developed by Golder Associates for the Environment Agency of England and Wales) simulates the fate of landfill gas arising from managed or unmanaged landfill sites.

Once the landfill gas and methane generation amounts are estimated, the next step is to estimate the amount of landfill gas that can be collected.

Collection efficiency is a measure of the ability of a gas collection system to capture landfill gas generated at the landfill. The landfill gas generation estimate produced by the model is multiplied

by the collection efficiency to estimate the volume of landfill gas that can be recovered for flaring or use in an landfill gas energy recovery project.

Even when a landfill only receives low or non-biodegradable waste, landfill gas collection might be necessary to avoid nuisance by odours; depending on the quality and the flow, if it cannot be used to produce energy it must be flared.

Flares are a component of each energy recovery option because they may be needed to control landfill gas emissions during startup and downtime of the energy recovery system and to control gas that exceeds the capacity of the energy conversion equipment.

The technology of a landfill gas flare is conceptually very simple: landfill gas is brought into contact with a supply of air and ignited. A variety of configurations of conduits and chambers can be used for the purpose. Whatever the exact design of the flare, however, it will comprise a number of basic elements, in addition to piping, valves and the body of the flare.

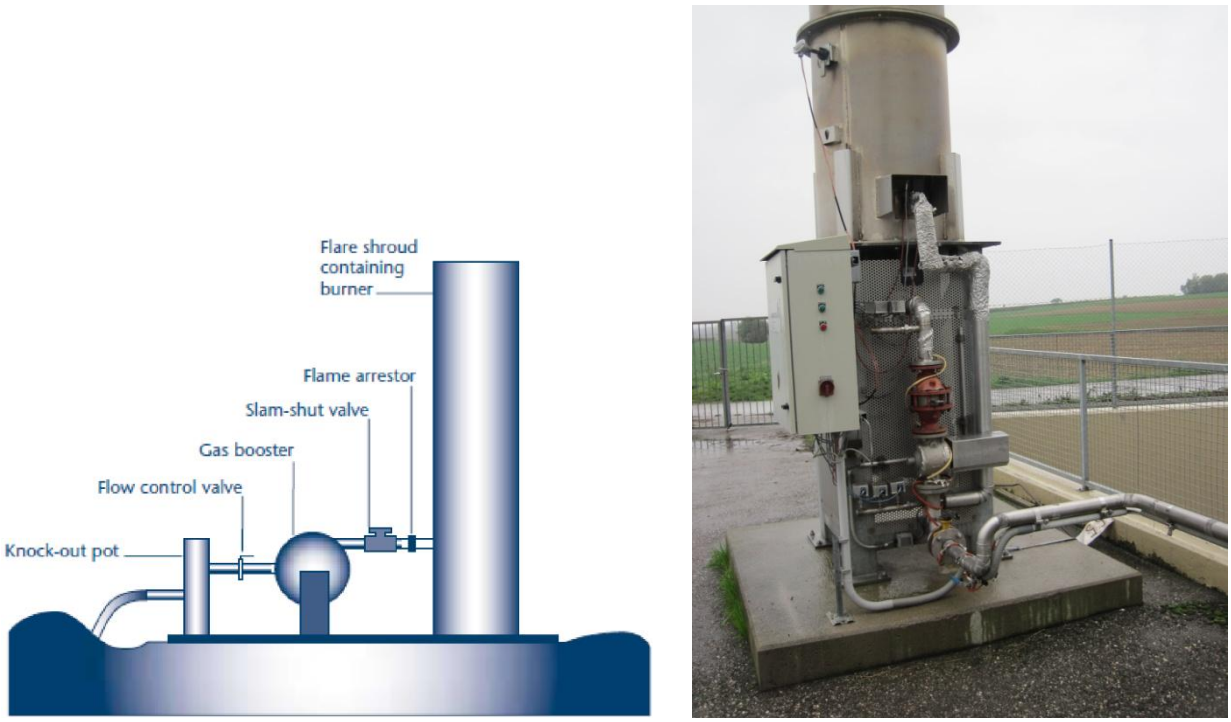

Figure 22: Landfill gas flare

Flare designs include open (or candlestick) flares and enclosed flares. Enclosed flares are more expensive but may be preferable (or required by state regulations) because they provide greater control of combustion conditions, allow for stack testing and might achieve slightly higher combustion efficiencies (higher methane destruction rates) than open flares. They can also reduce noise and light nuisances.

Landfill gas is flared at a temperature above 850°C (usually in the range between 1000 – 1200°C) to remove minor constituents in the landfill gas. For adequate destruction, combustion retention time is typically between 0.3 and 0.6 seconds. Continuous measurements of flow and temperature of biogas is usually required.

Figure 23: Landfill gas flares examples

7.5. Landfill gas monitoring

The process control has to be adjusted periodically. Sources (wells) with a low concentration of methane or high oxygen concentration will have to be closed more and sources (wells) with high methane concentration have to open more. The possibility to open and close underlines the necessity of control valves in the system with which the sources (wells) can be controlled individually.

If not properly monitored and controlled, landfill gas can give rise to flammability, toxicity, asphyxiation and other hazards including vegetation dieback. In addition to its explosive properties, landfill gas is also an asphyxiant when found in a closed space. It is therefore important to manage and control the gas generated within the waste to ensure that the risks associated with its movement are minimised.

The minimum explicit monitoring requirements for landfill gas from the Landfill Directive and Regulations relate to:

- The monitoring of gas within the waste (source);
- The efficiency of the gas extraction system;
- Atmospheric pressure (during borehole/well monitoring at the site).

A gas-monitoring programme has to be in place to establish whether gas production at the site is giving rise to a hazard or nuisance and to determine the effectiveness of the landfill gas management system. Landfill gas monitoring should be undertaken for the following main components:

- Source.
- Emissions.
- Air quality.
- Meteorology.

Landfill gas can be monitored from the gas extraction boreholes within the waste body and in gas wells around the perimeter of the landfill.

The following control methods can be performed:

- Continuous measurement of the amount of landfill gas that is extracted.
- Continuous measurement of the oxygen concentration in the gas with an alarm detecting system.
- Periodical measurement of the concentration of methane and CO in the landfill gas.
- Periodical measurement of the under pressure and of the concentration of methane, oxygen and CO_2 in the sources (wells).
- Periodic inspections of the waste that is landfilled on indications of gas leaking, as for example cracks in the slope, odour and vegetation damage.
- Periodic estimation of pumping system efficiency, by means of periodical measurement of the quality of the air surrounding the landfill and of the monitoring of surface gas emission.

Emissions to air of landfill gas can occur as either process gases from abatement plant or fugitive emissions from waste degradation. These can be effectively managed to minimise fugitive emissions, e.g., covering waste, effective gas collection, or controlling combustion conditions on a flare or utilisation plant.

The mass balance of gas in a landfill can be summarised by the following equation:

Total Gas Generated = Gas Utilised + Gas Flared + Lateral Emissions + Surface Emissions (including methane oxidation in the cap) +/- Short Term Storage

Figure 24: Energy power plants

Figure 25: Landfill gas piping

The Monitoring Plan must define trigger levels regarding the presence of landfill gas outside the landfill, including in the soil and subsoil, and must also include an intervention plan to be implemented and activated in case these thresholds are exceeded.

In cases where the pollutant is odorous, it may be appropriate to consider the odour threshold as a trigger level, provided that it is lower than the threshold for health or safety risks.

7.6. Odour Management

Odour from a landfill can be a significant source of complaints from the environment.

According to Annex I point 5 from the Landfill Directive, measures shall be taken to minimize nuisances and hazards arising from the landfill through emissions of odours and dust.

Annex I General requirements for all classes of landfills

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.

To take suitable measures, the landfill operator should first diagnose the odour problems by auditing the different processes on the landfill to determine and locate the different sources of odours arising from his landfill. Best practices in odour management are always facility-bound.

We can characterise different sources of odours on a landfill:

- Landfill Gas.
- Disposed waste.
- Leachate and leachate treatment.

In order to control the accumulation and migration of landfill gas, landfill gas must be collected in accordance with Annex I of the Landfill Directive, as described above. But even when a landfill gas management system is applied, emission of landfill gas can occur via:

- Surface and slope of the landfill.
- Leachate ponds.
- Leaks in the landfill gas collection system.

To deal with odour problems arising from landfill gas from leachate wells, the operator needs to assure leachate wells are covered and closed so landfill gas can not escape uncontrolled in the area.

The surface area emitting odours, directly influences the total odour emission for the site. The bigger the surface area, the larger the potential odour emission for the area is. Therefore, it is important to reduce the surface area to deal with odours due to landfill gas as due to the waste itself.
To realise a significant reduction, the landfill operator has to close a finished part of the landfill as soon as possible. It is important that deposition of the waste only occurs in one area instead of in different lots.

Each landfill layer is covered with an intermediary cover layer of at least 0,20 m thick to prevent litter and dust and odour pollution. At the end of the working day all deposited waste materials are covered with an intermediary cover. Substances causing unpleasant odours, are covered without delay. If subsidence, cracks, slides, holes, or places where the waste is not covered appear, these are covered with intermediary cover material on the day they are discovered.

Strong masking agents have been developed to cover bad odours with a more pleasant fragrance. This measure will not solve the problem, but only cover the problem. Beside that, complaints about odour problems caused by the (strong) masking agents, may arise. Therefore, it is wise to combine this measure with other odour management measures and never treat this as the one and only solution.

The operator can be asked to perform odours monitoring through dynamic olfactometry. Specifically, ouE/m³ and ouE/s are, according to the EN 13725 standard and the criteria provided therein, the units of measurement for odor concentration and odor flow rate, respectively. by means of. The inspector can check the results of the monitoring in order to assess if the impact on the receptors, according to the mathematical model, is still acceptable.

7.7. Best practice

BAT is to have a Landfill Gas Management Plan and system to prevent uncontrolled escape of gas from the landfill facility.

The procedures for demonstrating the effectiveness of the landfill gas controls are described in Annex III of the Landfill Directive and may include monitoring of soil gas outside of the landfilled waste and monitoring of fugitive emissions in addition to monitoring of the landfill gas conditions within the landfill (see the requirements in Annex III of the Landfill Directive).

The following BAT's can be identified:

Controlling the process

- Assess capacity of system (Engine/Flare & Booster capacity) and assess well coverage & performance (Extraction well coverage and assess performance of wells). The landfill gas extraction system should be monitored and adjusted regularly to maximise the collection of

landfill gas and minimise the inlet of air into the waste mass. The performance of the system should be monitored over time and steps taken to remediate any deterioration in performance and maintain landfill gas collection efficiency.

- Operational audits of the gas collection system should be undertaken annually to assess the efficiency of the system and to develop a programme of improvements.
- Assess landfill gas production (model used to estimate the gas production during the years).
- Prevent condensate build-up in gas collection network.
- Regularly monitor and balance gas extraction wells.
- Use automatic alert system to notify of utilization plant failure, where applicable.
- Backup power system for enclosed flares.
- Manage condensate to prevent emissions.

Controlling accumulation and migration

- Minimize landfill gas production potential by pre-treating the waste prior to acceptance for landfilling. Level above 1.000 mg O_2*$kgSV^{-1}$*h^{-1} of the Dynamic Respirometric Index may require a further treatment of the waste before landfilling. The threshold of 5% for TOC is another reference to decide about pretreatment for organic stabilization[17].
- Prevent landfill gas from migrating through the ground in both gaseous and dissolved states and prevent emissions of methane to the atmosphere. Maintenance of negative air pressure in the landfill gas extraction wells. Appropriate measures for landfill gas control are outlined in Section 3 of Annex I of the Landfill Directive. These include:
  - Lining of the landfill base and sides to create a low permeable barrier to sub-surface gas flow.
  - Surface sealing including impermeable mineral layers and gas drainage layers.
- Use of horizontal and vertical gas collection pipework in the waste body.
- Selection of appropriate cell sizes.
- Use of appropriate materials for temporary cover, interim and final capping.
- Landfill gas extraction should start as soon as possible following the deposit of the waste.
- All landfill infrastructure that protrudes through the surface of the waste or capping layer, such as leachate or gas wells, should be sealed to prevent emissions of landfill gas.

Monitoring

To comply with the requirements of the Landfill Directive, landfill gas monitoring should be undertaken. The monitoring of landfill gas is an essential factor in the management of any landfill site. A monitoring and sampling plan must be prepared and set out within the Landfill gas management Plan. The monitoring plan should provide objectives and describe a site-specific programme of monitoring to be undertaken at the landfill site. This will incorporate:

- The type of monitoring to be undertaken.
- The methods of monitoring (including detection limits, accuracy, etc.).
- Monitoring locations.

[17] These references are indicated within the ISPRA Guideline on pretratment of waste before landfilling (ITALY) - https://www.isprambiente.gov.it/it/pubblicazioni/manuali-e-linee-guida/criteri-tecnici-per-stabilire-quando-il-trattamento-non-e2019-necessario-ai-fini-dello-smaltimento-dei-rifiuti-in-discarica-ai-sensi-dell2019art.-48-della-l.28-dicembre-2015-n.221

- Frequency of monitoring.
- Appropriate action/trigger levels necessitating action.
- Appropriate action plans to be implemented should any levels greater than the trigger levels be recorded.

Regular monitoring (which may include monitoring of fugitive gas emissions, dynamic olfactometry) and immediate remediation should take place for all sealing systems (e.g. caps) and landfill infrastructure to ensure that leaks are detected and repaired as soon as possible.

Monitoring data must be reviewed on a regular basis against the initial objectives of the Landfill gas Management Plan. The monitoring frequency must not be regarded as fixed for any site.

Landfill gas monitoring should be undertaken for the following main components:

- Source.
- Emissions.
- Air quality.
- Meteorology.

The aim of source monitoring is to characterise the quantity and quality of the gas in each section of the landfill. Routine monitoring to determine the composition of this gas is typically undertaken using portable hand-held instruments. These instruments measure the bulk components within the landfill gas and associated physical parameters Two different types of source monitoring points are found on landfill sites: collection wells and monitoring wells.

Emissions monitoring on landfill sites will typically consist of:

- Surface emissions.
- Lateral emissions.
- Combustion emissions.

VOC surface emissions surveys can be a fast, reliable and cost effective method for identifying significant emission sources of landfill gas from a landfill surface, and for demonstrating compliance after remediation of such emission sources.

VOC surface emission measurements can provide the following information:

- The location of the main sources of surface emissions on the site.
- Identify faults in the gas management system and to prioritise the remediation required.
- Whether previous remediation effort has been successful.
- Where significant amounts of landfill gas that could otherwise have been flared or beneficially used for power generation are being lost.
- Measure the total emissions from the site of methane, an important greenhouse gas involved in global warming.
- Where the licensee may need to focus remediation efforts to improve the gas collection efficiency.

A qualitative estimate of methane emissions through a surface cap can be made using a hand-held instrument such as a flame ionisation detector (FID). However, very low flux cannot normally be detected and localised on a landfill cap.

Extensive research suggests that the flux box is currently the most cost effective technique for the verification of the range of surface emission sources typically found on a landfill site. Flux boxes are enclosed chambers used to measure the rate of change in methane concentrations above a specific, small area of the landfill surface. By measuring the flux at a number of representative sampling points, an estimate can be made of the total emissions from a zone.

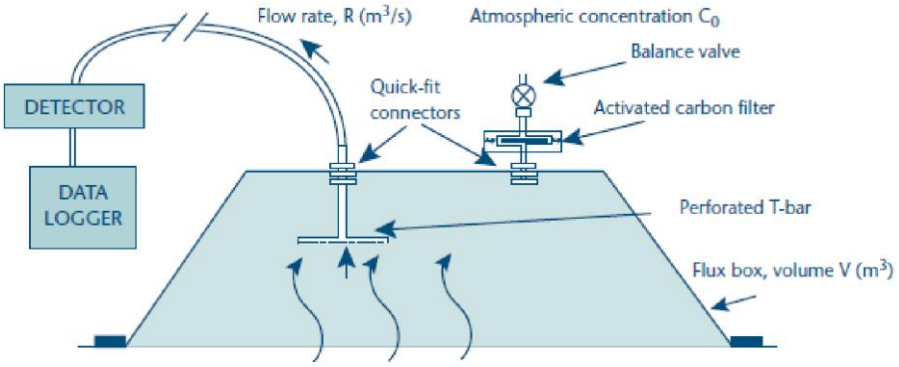

Figure 26: Flux box

To record surface concentrations of methane walk-over surveys can be produced using GPS data logging and handheld instruments that enable areas of high methane concentration or emission to be identified; they do not quantify flux.

Figure 27: Methane walk-over surveys

The monitoring of lateral emissions is undertaken using gas monitoring boreholes outside the perimeter of the deposited waste. These boreholes can be located both on-site and off-site. They provide information on the movement of landfill gas below the surface of the landfill from the waste mass. The monitoring of external boreholes is essential to demonstrate the efficient management of gas within the site and to detect any gas migrating from the site.

The monitoring of air quality within and around landfill sites is becoming increasingly important.

Figure 28: Air quality monitoring system

Drones are used nowadays to monitor landfills through thermal imaging aimed at controlling areas most affected by diffuse emissions by detecting temperature profiles. This cutting-edge technique promises to monitor emissions released from the underground as they rise toward the surface, using heat differentials.

Drones will enable us to quickly detect abnormal temperature differences, allowing us to identify biogas diffusion phenomena or possible signs of self-combustion.

Use and estimation of the landfill gas

- Collect all landfill gas and, where feasible, utilize it to produce energy. According to the Italian law (Decree n.36/2003), the energy reuse can be performed in case of a minimum production of truly extractable biogas characterized by a capacity of not less than 100 Nm^3/h and by a duration of the expected flow to the minimum values not less than 5 years.
- If the composition is suitable and transfer into the natural gas grid is possible and permitted, this can be an option.
- Where energy generation from landfill gas is not possible, it should be burned in an enclosed flare; control the combustion conditions of enclosed flares, in terms of the carbon monoxide concentration, temperature and retention time by ensuring that combustion occurs at 850-1,000°C with a product retention time of 0.3 seconds within the combustion zone and an oxygen concentration above 3%.
- Follow the hierarchy of landfill gas treatment options:
    - Landfill gas utilisation for energy recovery,
    - Transfer into a natural gas network,
    - Enclosed flaring,
    - Venting with open flaring as odour control measure.

The operator should model and estimate the generation of landfill gas throughout the lifecycle of the site as a guide to the design and phasing of the gas extraction scheme. There are a variety of gas generation models commercially available which can predict landfill gas generation based on the types and quantities of waste accepted at the site. The model should be kept up to date using site specific data such as actual waste inputs.

Odour management

In accordance with the BAT to develop and apply an Environmental Management System it is also BAT to implement an Odour Management system to deal with odour emissions and odour complaints from the environment.

- Map odour emissions by for example field inspections (on the landfill and in the area), e-noses, odour studies performed by external experts or laboratories, ecc.).
- Odour audit: analyse the different processes on the landfill that can contribute to an odour problem and determine and locate the different sources of odours arising from the landfill.
- Register odour complaints.
- Direct communication / interaction with local residents and Competent Authorities.
- Carry out facility-bound measures to prevent and tackle odour emissions.
- Follow up measures and complaints.

7.8. Inspection preparation: desk study

During the desk study, the following preliminary check should be performed in order to collect the necessary information for a comprehensive inspection:

Permit and permit application

- Provisions of the permit: collecting system, biogas parameters.
- Gas extraction system efficiency: check conditions in the permit and description in permit application.
- Gas flaring torch: check conditions in the permit and description in permit application.
- Gas trigger level: check conditions in the permit and description in permit application.
- Risk assessment results.
- Results of the landfill gas diffusion model.

Self monitoring Report

- Assess compliance with all Self monitoring requirements (lab methods, frequency, parameters).
- Emissions results: check compliance with ELV for engines (energy use).
- Comparing the model and the real flux and composition.
- Monitoring data - Diffuse emissions from the body of the landfill – sampling methodology.
- Organic amount in the waste.
- Basic characterization: information about treatment of organic waste.
- Odour measurements results.

7.9. On site Inspection

During the on-site inspection, the inspector should assess and check that the landfill gas control system is properly well constructed, operated and maintained. A landfill gas extraction has to be installed as soon as possible in order to minimise the release of uncontrolled landfill gas emissions.

The inspector will check if a landfill gas management plan is implemented and performed according to good operational practices (e.g. not leaving odorous waste uncovered).

Flares should be operative at any moment. The presence of perimeter landfill gas monitoring boreholes should be checked to monitor gas migration.

Operational data, such as flow rate, pressure, temperature and inlet gases will be registered.

The inspector can check the quantity of organic waste entering the landfill and if a treatment has been performed according to art. 6 of the Landfill Directive.

7.10. Existing guidelines

Organisation	Title of document
Environment Agency & SEPA (UK)	Guidance on the management of landfill gas[18]
EU Commission	Landfill Gas Control -Guidance on the landfill gas control requirements of the Landfill Directive[19]
EPA Ireland	Air Guidance Note 6 (AG6) Surface VOC Emissions Monitoring on Landfill Facilities[20]
ISWA	Landfill operational guidelines 2nd edition[21]
EU LIFE+ project	ACUMEN project report - Managing landfill gas at closed and historic sites[22]
Germany **Factory Inspectorate of Lower Saxony** **Staatliches Gewerbeaufsichtsamt Hildesheim**	Waste management facts 19.1 Landfill degassing in case of declining gas volume[23]
Reconnet (Italy)	Determination and Management of Warning Levels for Landfill Monitoring[24]

18 https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/321606/LFTGN03.pdf

19 https://ec.europa.eu/environment/topics/waste-and-recycling/landfill-waste_en

20 https://www.epa.ie/pubs/advice/air/emissions/AG6.pdf

21 http://www.wief.net/programs_events/ISWA_Landfill_Operational_Guidelines_2nd_Edition%5B1%5D.pdf

22 https://landss.soton.ac.uk/sites/landss.soton.ac.uk/files/attached_files/node-39/151203-acumen-project-report.pdf

23 https://www.gewerbeaufsicht.niedersachsen.de/startseite/umweltschutz/kreislauf_und_abfallwirtschaft/abfallwirtschaftsfakten/abfallwirtschaftsfakten-52057.html

24 https://www.reconnet.net/Docs/Bonifiche_discariche_REV%200.pdf

8. WATER PROTECTION AND MANAGEMENT

In this chapter all water sources in and on landfills are covered. It concerns the following types of water:

- Groundwater
- Leachate
- Surface water
- Rainwater
- Run-off water

For these types of water the following definitions apply:

Groundwater: the water beneath the surface of the ground.

Leachate: any liquid that, in the course of passing through matter, extracts soluble or suspended solids, or any other component of the material through which it has passed.

Surface water: water on the surface of the planet such as in a stream, river, lake, wetland.

Rainwater: water which has fallen as rain.

Run-off water: that part of the precipitation, snow melt, or irrigation water that appears in uncontrolled (not regulated by a dam upstream) surface streams, rivers, drains or sewers (on the top surface of the landfill).

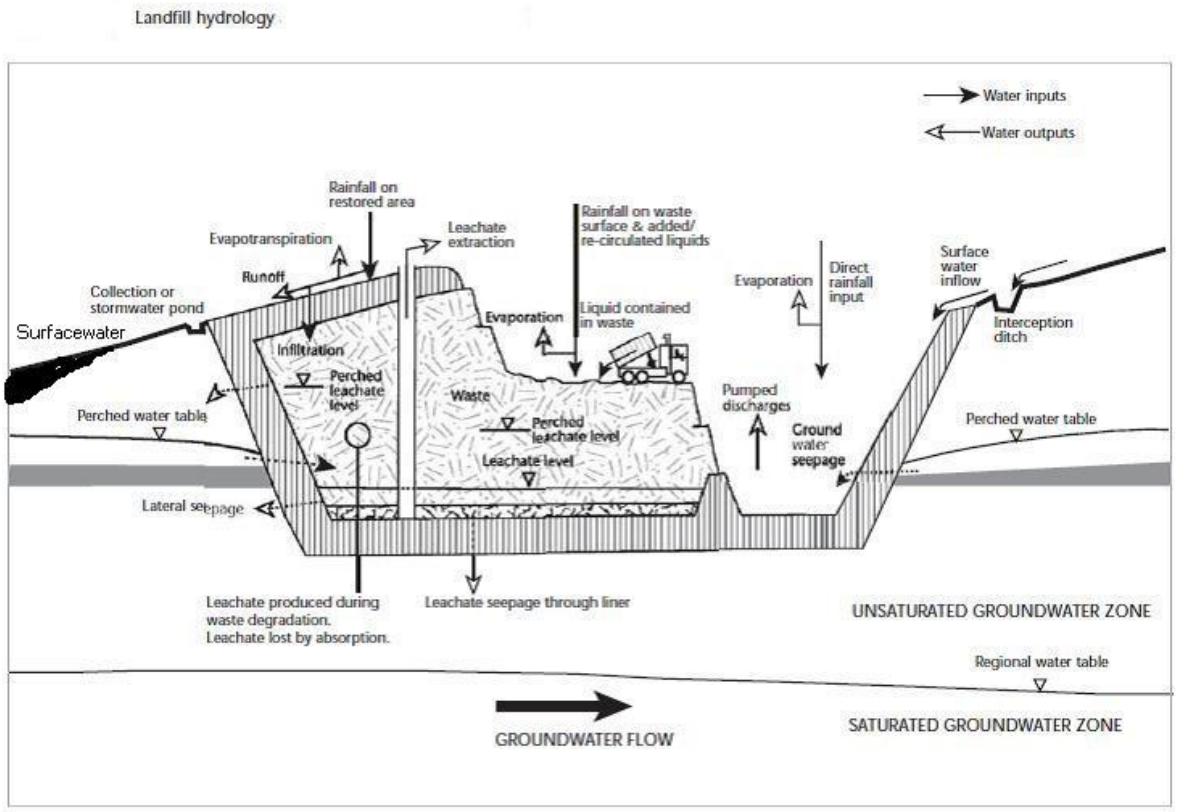

Figure 29: Landfill hydrology (source: Landfill Guidance, Environment Agency UK, February 2003)

8.1. Protection of soil and groundwater: law requirements

According to the Directive 1999/31/EC "*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 […]. 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 top liner during the passive phase/post closure*."

These geological boundary conditions are decisive for landfill site selection and have to be taken into account accordingly for issuing the permit:

Table 6: Landfill Bottom and Top requirements

		Hazardous	Non hazardous	Inert
Bottom	Geological barrier / artificial barrier	Required	Required	Member States decision
	Artificial sealing liner	Required	Required	Member States decision
	Drainage layer	Required	Required	Member States decision
Top	Gas drainage layer	Not required	Required	Member States decision
	Artificial sealing liner	Required	Not required	Member States decision
	Impermeable mineral layer	Required	Required	Member States decision
	Drainage layer> 0,5 m	Required	Required	Member States decision
	Top soil cover > 1 m	Required	Required	Member States decision

With regard to groundwater protection the best way is to situate the landfill at ground level rather in a quarry or other similar depression. This allows the leachate to drain freely and means that it does not have to be pumped. After closure and if the leachate doesn't need to be treated any longer, aftercare will be simpler and have lower costs.

The following annexes of the Landfill Directive contain conditions on protection of soil and groundwater in a landfill:

BOX 7. Protection of soil and water

Annex I

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 land filled 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.

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 top liner during the passive phase/post closure.

3.2 The geological barrier is determined by geological and hydro geological 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:

- landfills for hazardous waste: K <= 1,0 x 10^{-9} m/s; thickness > 5 m
- landfills for non-hazardous waste: K<= 1,0 x 10^{-9} m/s >; thickness> = 1 m
- landfills for inert waste K <= 1,0 x 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 meters 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	not 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 basis of an assessment of environmental risks taking into account in particular Directive 80/86/EEC (until 22 December 2013 then replaced by Directive 2006/118/EC) the competent authority has decided in accordance with section 2 that collection and treatment of leachate is not necessary or it has been established that the landfill posed 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.

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

Annex III

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 hydro geological 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.

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

	Operation phase	**After-care phase**
Level of groundwater	every six months	every six months
Groundwater composition	site-specific frequency	site-specific frequency

C. Trigger level

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 hydro geological formations in the location of the landfill and groundwater quality. The trigger level must be laid down in the permit whenever possible.

Emission data: water, leachate

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.

Monitoring of surface water if present shall be carried out at no less then two points, one upstream from the landfill and one downstream.

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, burried etc). This has to be specified in the permit

	Operating phase	After-care phase
2.1 Leachate volume	monthly	every six months
2.2 Leachate composition	quarterly	every six months
2.3. Volume and composition of surface water	quarterly	every six months

8.2. Description

Protection of soil, groundwater and surface water is to be achieved by the combination of a geological barrier and a bottom liner combined with a leachate collecting system, (when required) during the operational/active phase and by the interaction of a geological barrier the bottom layers, the leachate collection (where required) and a top liner during the passive phase/post closure.

In addition to the geological barrier, sealing layers, sealing system and leachate collection (if required), it must be ensured that the accumulation of leachate at the base of the landfill is reduced to a minimum. This can also be achieved by using small landfill sectors. In most cases leachate has to be treated before discharging / draining.

In order to check if all measures taken are in order, inspection and monitoring is essential. It is legally required to monitor discharged leachate, quality of surface water (up and down-stream) and quality of groundwater (up-and downstream of the landfill).

8.3. General measures for protection of soil and groundwater

From a precautionary point of view it is important to keep the groundwater out of the landfill and leachate water in the landfill.

If the basis and slopes are not covered with a sufficient mineral or other layer, contaminants can enter the soil and groundwater. A bottom layer can also get damaged whereby groundwater (from outside) can enter the landfill and get contaminated by leaving the landfill. Leachate can also penetrate the soil if the covering is not present, insufficient or damaged. Through this way contaminants can reach the groundwater.

Useful notes:

- Taking into account the geological / hydrogeological conditions where a landfill shall be built is very important. The risk of groundwater contamination has to be minimized, better completely ruled out.
- Before planning a landfill it is very important to clarify if the location is suitable. If suitable, perform a Hydrological Risk Assessment (HRA) to determine which measures are necessary to protect the groundwater when building and during the operation of a landfill.
- Keep the minimum standards for a geological barrier as stated in the Landfill Directive or preferably exceed the standard.
- Create a monitoring plan with a map with boreholes for monitoring groundwater level and quality and if necessary, measuring points to determine surface water quality.
- Place, based on the HRA, a sufficient number of groundwater wells up, side and downstream the location to monitor groundwater level and quality.
- Determine the trigger levels of the relevant substances, based on the risk assessment and waste input.
- Determine the groundwater level and quality before starting a landfill and during operation.
- Set maximum groundwater levels and trigger levels of groundwater quality in the permit. In some Member States, trigger levels are stated in national legislation.
- Determine an action plan in the permit in the case that the set groundwater levels or groundwater quality trigger levels are exceeded.

Figure 30: Groundwater monitoring in Spain

8.4. Best practice

In order to prevent pollution of ground and surface water, a landfill has to meet a number of requirements. The goal is to keep pollutants inside the landfill and to treat polluted water before discharging it. These tasks are normally regulated in the permit.

Some best practice examples to achieve these requirements:

- Carry out an hydrological risk assessment and repeat periodically (e.g. every 6 years as in GB). Although this is essential as a base for the environmental permit and normally performed before the permit is issued, it is a good practice to repeat this assessment periodically.
- During construction and also during the operational phase of a landfill, soil, surface and groundwater must be protected by a construction under the landfill which prevents water from entering into the landfill from underneath it and leaving from it. At the same time, the landfill must contain systems to control water which enters the landfill, like rainwater. To prevent runoff water from spreading into the environment, it is best practice to build a landfill so that runoff water from polluted areas cannot leave the sealed landfill.
- Install a complete monitoring system for groundwater, surface water, leachate and drainage water including threshold values for the relevant substances. This should be done in addition to the risk assessment. Depending on the current (pre-building-phase) quality of ground and surface water, an action plan is to be developed. This plan has to contain measures if thresholds are exceeded.

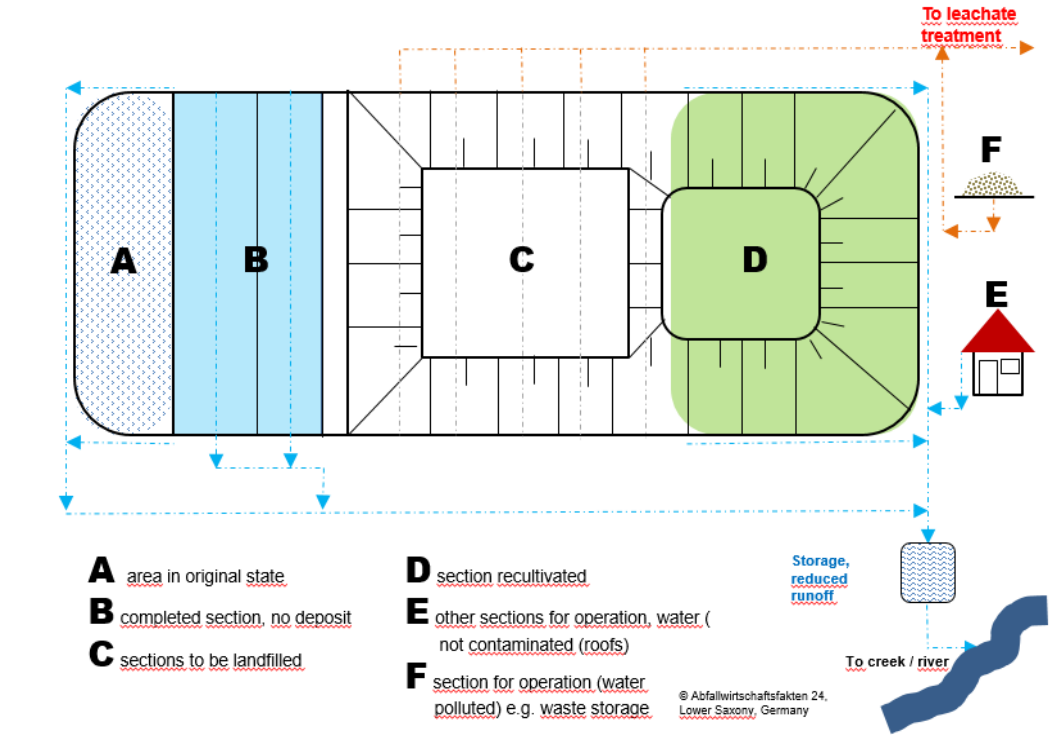

Figure 31: Schematic for leachate and rainwater collection system (Germany)

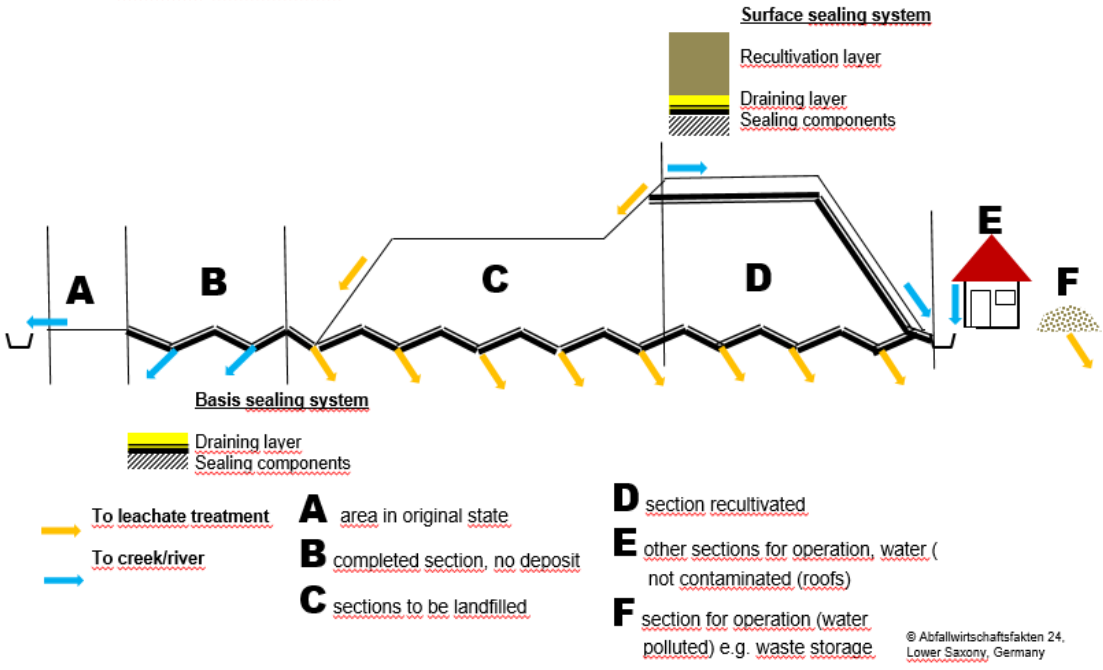

Figure 32: Schematic for separate discharge of leachate and rainwater during operation (Germany)

- It's also best practice to construct a leachate collection system in a way so it doesn't have to go through the bottom liner. In this way there are no weak spots in the bottom liner. The most

important factor is to avoid creating leachate. For example, work with small cells and separate leachate collection from cells of hazardous and non-hazardous waste. By collecting different leachate streams, each one can be treated in a specific way.

- To prevent odour from collected leachate in leachate basins it's best practice to cover the surface with a liner.
- Best practice is also to install a complete monitoring system for groundwater, surface water, leachate and drainage water, including threshold values for the relevant substances. This should be done in addition to the risk assessment. Depending on the current (pre-building-phase) quality of ground and surface water, an action plan is to be developed. This plan has to contain measures if thresholds are exceeded.

8.5. Trigger levels / thresholds for groundwater

The evaluation of monitoring data from landfills assumes a central importance in verifying the effects related to the presence of the landfill on the groundwater matrix and in preparing any mitigation actions to minimize its impacts.

Since the precautionary principle must be applied to a landfill site, groundwater pollution has to be prevented. To determine whether the landfill affects the groundwater, the quality of the groundwater upstream and downstream must be compared. Depending on the existing groundwater quality and the geological conditions, trigger levels / thresholds should be defined.

Trigger thresholds are groundwater monitoring values, above which measures have to be taken into account to protect groundwater. Since natural groundwater quality may vary, it is not helpful to determine fix levels / concentrations, but rather specify a range for each monitoring point. Additionally, it might be necessary to assess the values from time to time and adjust them if required.

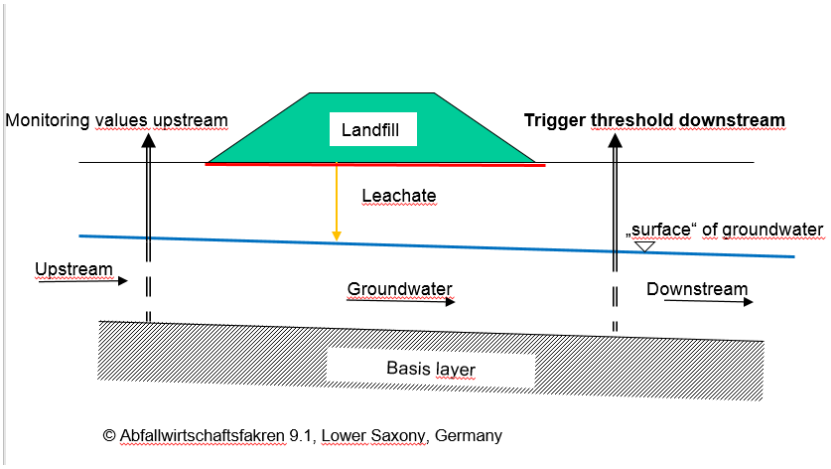

Figure 33: Trigger thresholds, spatial allocation (Example Germany, Lower Saxony)

The trigger thresholds must be established by the competent authority before storage of waste begins.

Because of the potential retention and degradation processes as well as dilution on the flow path to the groundwater measuring point, heavy metals are not really suitable for early recognition of landfill-related contamination. Better suited for the early detection of landfill-related main pollutants are salts and the organic sum parameters AOX and DOC.

Example for trigger levels (Germany)

It might be good practice to set two types of trigger thresholds

- Trigger-Threshold A = warning value, Impairment is detected,
- Trigger- Threshold B = if threshold A is exceeded and contamination is feared. Threshold B has to be determined on a case by case basis for each substance. Values are to be defined from which, a contamination of groundwater has to be assumed.

The trigger-thresholds (A) are to be calculated as the difference between upstream and downstream measurement values. The relevant upstream values can be found out by calculating a scatter band from the time series of the measuring points. (Example arithmetic average of all values +/- double standard deviation - Filed in MS-Excel) Then trigger-threshold (A) can be determined by addition of a substance-specific differential value. For the time series of the upstream measuring point a period of 10 years is usually sufficient

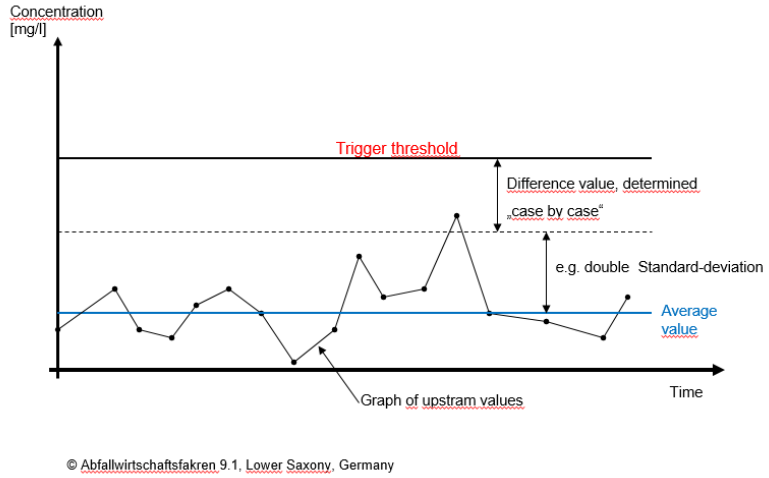

Figure 34: Determine trigger thresholds (example Germany, Lower Saxony)

If the trigger threshold A is exceeded, the trigger level B should be set. Here, not only the differential values of up- and downstream are to be considered, but also values are to be defined from which, in a concrete individual case, pollution of groundwater can be assumed. This for example can go beyond the determination of salts, AOX and DOC.

If the trigger threshold B is exceeded, a case by case risk assessment is mandatory to determine if a contamination has taken place. Furthermore, additional actions have to be taken into account.

Actions to be taken if thresholds are exceeded

Threshold A: steps of an action plan

After each step, a decision must be made whether the next step must be initiated. If, despite a trigger threshold being exceeded, it has been decided that no further action is necessary, a decision on further steps is required if the values change significantly. The following steps can be envisaged:

1. the detailed description of the temporal development of up- and downstream measured values,
2. verification of the measured values in a short term, if necessary by repeating measurements,
3. adjustment of the threshold A, if necessary,
4. the determination of trigger threshold (B), if necessary

5. assessment of the exceedance with regard to groundwater pollution (indicative investigation and, if necessary, detailed investigation) by a suitable expert
6. identification of the cause of the exceedance,
7. presentation of the effectiveness achievable by a surface sealing
8. study of the feasibility of further technical measures going beyond the surface sealing.

The action plan should contain furthermore:

1. who is to be involved in the decisions in each case (e.g. competent authorities).
2. and following information:

- possible area of influence of the landfill,
- person responsible for updating the plan,
- person responsible for implementing the measures,
- who should be informed and when? (e.g. authorities, waterworks, public),
- date of establishment of the action plan.

Threshold B:

Developing measures /actions based on an assessment and case by case decisions e.g.:

- establish a top sealing
- pump and treat of contaminated groundwater
- constructional measures e.g. cut off (leak proof wall).

Example for trigger levels (Italy)

The Italian Reconnet Guidance[25] "Determination and Management of Warning Levels for Landfill Monitoring" presents a methodology or procedure for managing groundwater monitoring data, through the identification of site-specific markers, the definition of threshold levels, and intervention procedure matrices.

To determine the threshold levels it is emphasized that the general approach must necessarily be adapted to the specific context in which it is applied.

In particular, the procedure includes the following phases:

1. **Definition of the conceptual site** model through:
    a. characterization of the leachate;
    b. characterization of the aquifers (background concentration);
    c. location and description of potential sources of contamination and migration pathways.

2. **Selection of markers** considering the following characteristics and properties of the substances:
    a. mobility of the substances (value of the partition coefficient Kd);
    b. differential concentration leachate/aquifer;
    c. lack of correlation with other substances identified as markers.

3. **Evaluation matrix** which consists of:
    a. calculation of control and threshold limits;
    b. evaluation criteria;
    c. intervention matrix.

[25] https://www.reconnet.net/Docs/Bonifiche_discariche_REV%200.pdf

The intervention matrix or plan identifies the actions to be taken in different situations where control and/or alarm levels are exceeded. It can be developed on two threshold levels, allowing the speed of intervention to be adjusted according to the significance of the observed event (in terms of increased concentration of the markers). Having two threshold levels enables a deeper understanding of the current situation in the event that the first threshold is exceeded and allows for the implementation of actions only upon exceeding the second threshold.

The exceeding of the specified thresholds must occur simultaneously for all identified markers. If the exceedance is limited to a smaller number of markers, no intervention is planned.

Markers can be monitored on a monthly basis on all the piezometers.

Table 6: Intervention matrix

Threshold (trigger levels)	**1st exceeding event**	**2nd exceeding event**	**3rd exceeding event**	**4th exceeding event**
Control	Repeat GW monitoring at the piezometer within xx days	Repetition in the piezometer every XX days until the thresholds are met	Extension of the verification to all piezometers and repetition every XX days until the thresholds are met	Investigation Plan
Alarm	Repeat GW monitoring at the piezometer within xx days	Investigation Plan		

8.6. Leachate management

The collection and treatment of leachate also continues to be a major management issue facing landfill operators. Wastes which are put into landfills contain water; rainwater also penetrates non-covered landfills. This water will sink through the waste that is put into the landfill and will eventually reach the bottom of the landfill. Leachate contains all sorts of contaminants from the waste.

Most important is that the amount of leachate must be kept to a minimum which implies the following:

- Work with small cells for landfilling the waste. Compact and cover as soon as possible completed cells.
- Collect the leachate with a drainage system in a basin.

A requirement for the biological degradation of organic waste, is that they have sufficient moisture. This is the case especially in old landfills where waste with a high organic content, such as household waste, household-type industrial waste and sewage sludge, has been deposited. If there is not sufficient moisture, it can be adjusted by targeted and controlled infiltration. The amount of water required to maintain the biological conversion processes is often overestimated. It is in the order of 3 to 30 l/(m^2year). The use of drinking and surface water for humidification can inhibit the biological conversion processes in the immediate infiltration area. Therefore landfill leachate should be used for this targeted “rewetting” normally after pre-treatment. The infiltration systems should be designed in such a way that they do not tend to clog and can be regenerated or renewed without great effort.

Depending on the Member State and on the Competent Authority, leachate recirculation in the landfill body may or may not be allowed. On the one hand, leachate recirculation results in the

benefits of a faster stabilization of the landfill, and enhanced biogas production as it restores the content of humidity in the waste; on the other hand, the recirculation of excess leachate, where additional leachate no longer provides any benefit, is seen as leachate disposal at a landfill and is not an appropriate option for managing it. The collected leachate must be treated before discharging into surface water.

The European Commission, in the opinion Ref. ARES (2023)8588800 of December 14, 2023, highlighted that the current provisions of the Landfill Directive do not explicitly prohibit the reintroduction of leachate into the waste body. However, they emphasize that, pursuant to Article 5, paragraph 3, letter a) of Directive 1999/31/EC, the disposal of liquid waste in landfills is not permitted.

Furthermore, answering to a formal request of the Italian Ministry of Environment, highlighted the following:

i) If leachate is reintroduced without proper treatment, salts, heavy metals, and nitrogen could accumulate in the recirculated liquid and could inhibit the biodegradation process within the landfill;

ii) The recirculation of liquids within the body of a landfill may compromise the stability and settlement behavior of the site, potentially causing issues such as landslides.

The EU COM, therefore, in the absence of an explicit prohibition on the recirculation operation in the EU provisions, assign the competent authorities responsible for granting the operating permit for the facility a specific responsibility in terms of evaluation. This evaluation should be based on the physico-chemical characteristics of the leachate and the physico-mechanical characteristics of the facility, assessing the feasibility of carrying out the recirculation operation, as well as issuing operational requirements related to the monitoring and control of any authorized operations.

When it isn't possible to recycle the leachate it has to be discharged:

- Collect the leachate and check the quality of the leachate.
- If it is necessary, treat the leachate before discharging.
- Check the quality and quantity (pre and post treating) of the leachate periodically.

In the case of very heavy rainfall (unplanned events), larger quantities of leachate are produced. This leachate must also be stored so that it cannot threaten ground or surface water. This "leachate wave" mostly sets in only a few hours after heavy rainfall. It does not make any sense to pump and return the leachate to the landfill site, because the rainfall event is prolonged by returning leachate. The water would only be pumped in a circle.

Figure 35: Lagoon for treated leachate water at Landfill in Romania

In such an exceptional case, it seems more appropriate to allow backwater, possibly even into the drainage layer of the landfill base. The technical framework conditions, such as proof manhole covers or closed collection pipes / cleaning flaps, as well as the height of the lower edge of the waste deposit should be taken into account and evaluated in time.

Figure 36: Leachate monitoring in Malta

Figure 37: Leachate treatment in Portugal

After definite closure and aftercare, and if treatment of leachate is no longer required, it should be the goal to drain leachate directly to the receiving waters.

Requirements:

- Recultivation and aftercare have ended
- Leachate can be drained directly because no longer polluted
- Monitoring recommended

Different options, depending of the construction of the landfill are possible, as shown below:

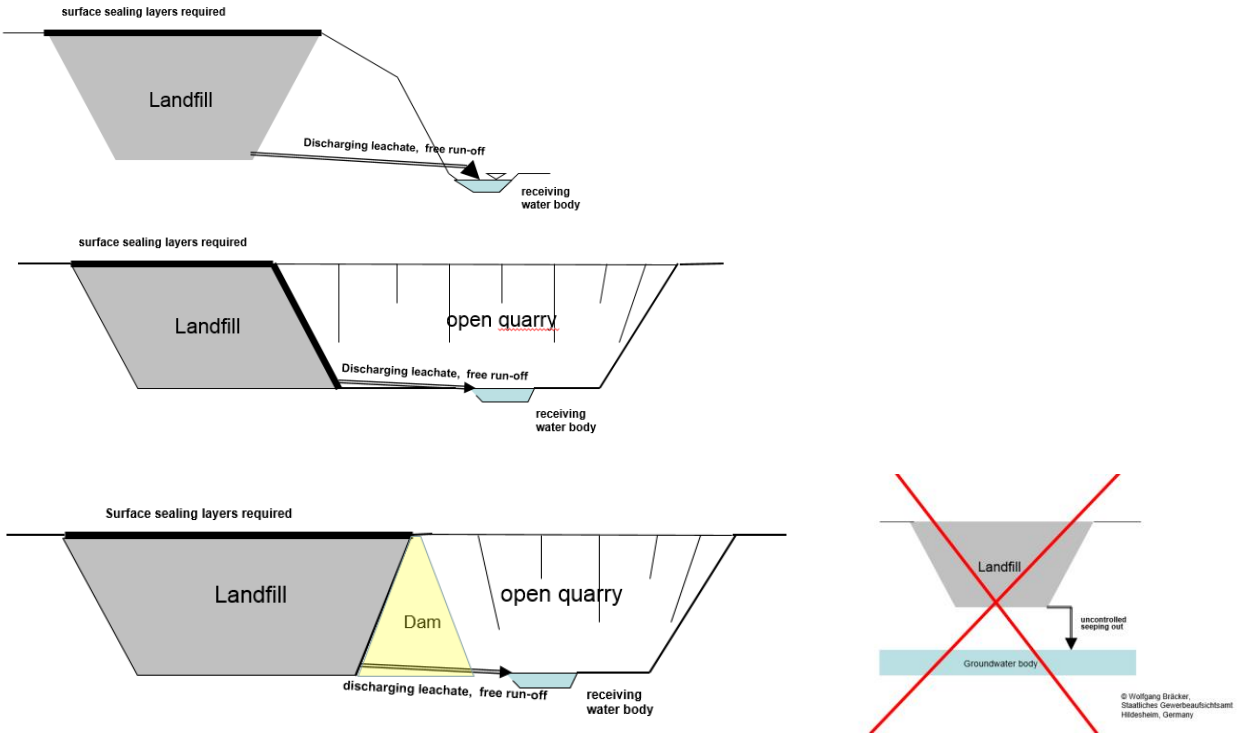

Figure 38: Principle for "free run off-water" when aftercare has ended

According to the Landfill Directive, contaminated water and leachate collected from the landfill must be treated to the appropriate standard required for their discharge.

The collection and treatment of LFL presents technical and logistical challenges for landfill operators. As it is often not possible to treat leachate on site, it is common practice to transfer leachate to wastewater treatment plants (WWTPs) and co-treat it with domestic sewage. To date, there has been limited investigation into the environmental impacts of co-treatment of landfill leachate and municipal wastewater in WWTPs.

On the other hand, several new technologies and processes to treat leachate are being developed which can be adopted and deployed in conventional WWTPs. For example, floccular activated sludge has evolved to granular sludge processes; shortcut denitrification processes can potentially lower the oxygen and carbon requirement for nitrogen removal; membrane processes can provide higher effluent quality; more advanced aeration methods enhance energy efficiency, instrumentation and control; and automation capabilities have increased.

Several projects in the EU have focused on treating landfill leachates, including the CLEANLEACHATE project, which explored a treatment system for the removal of refractory organic substances and ammonium by oxidation processes without chemical additives in LFLs; and the OXFLOC project, which aimed to reduce treatment costs of industrial wastewater in Europe and has been tested with leachate[26].

Additional best practices concerning leachate

- To avoid weak spots in the sealing system, design the leachate collection system and the pipes for draining the leachate collection system so that they do not have to penetrate the bottom liner or the slopes.

[26] Source: European Environment Agency

- The most important factor is to avoid creating leachate. For example, work with small cells and separate leachate collection from cells of hazardous and non-hazardous waste. By collecting different leachate streams separately, each one can be treated separately.
- Cover the surface with a liner to prevent odour from collected leachate in leachate basins

8.7. Surfacewater, Rainwater an Meteoric Water

Surfacewater

Treated leachate, groundwater and run-off water can eventually reach surface water if it's in the surroundings of the landfill. If these different types of water are contaminated it can potentially pollute the surface water. To prevent pollution of the surface water, the sources should be monitored at a discharging point to be identified in the permit.

Rainwater

Rainwater can enter a landfill site when it is not covered. In this case rainwater becomes leachate. It can also run off through roads and slopes of the landfill. In that case this water is mostly slightly polluted. When we want to discharge this water, it has to be treated. Light treatment will be sufficient.

Run-off water

Completed cells coverage is crucial to prevent run-off water from coming in contact with waste. If run-off water has been in contact with the waste, treatment before discharging is necessary. Run-off water can be monitored to check the presence of contaminants.

8.8. Inspection preparation: Desk study

Before starting the on-site inspection, inspectors have to prepare the inspection by a desk study. They have to check the following components for inspection on water management on a landfill:

- What measures are described in the permit and/or permit application about:
    - Groundwater monitoring (trigger levels, monitoring frequency).
    - Collection, treatment and discharge of leachate.
    - Run-off water.
- Is a risk assessment of the landfill part of the permit?
- Is an action plan stated in the permit in case of exceeding the groundwater trigger levels?
- What are the results of leachate monitoring?
- What are the results of maintenance of leachate collection system ?
- Check previous inspection reports.
- Check the monitoring results.
- Make a comparison between groundwater quality up and downstream of the landfill to check if groundwater is polluted by water coming out of the landfill.
- Check if there are complaints.

Use all of the above information to check if all the necessary actions are taken by the permit holder and if the installation is well maintained

This is to ensure that the landfill doesn't threaten the quality of the groundwater or near surface water.

8.9. On site Inspection

During the on-site inspection inspectors check if all necessary measures are taken by the holder of the permit to meet the permit requirements. Information which is found during the desk study is also checked during the on-site inspection.

What can you check during an on-site inspection?

Groundwater:

During the inspection the following should be checked or performed:

- The wells for groundwater sampling are present at the right spots and functional.
- Make a comparison between groundwater quality up and downstream of the landfill to check if groundwater is polluted by water coming out of the landfill.
- Check the monitoring results if they are available at the landfill.
- Groundwater quality can be checked by taking samples up and downstream of the landfill. Depending on national legislation inspectors can perform it themselves or it is performed or commissioned by the landfill owner. Sampling has to be performed by qualified operators and usually accreditation according to EN ISO/IEC 17025:2018 is required to analysis laboratories.

Leachate:

- Check if the leachate collection system is clean and unclogged to prevent a buildup of leachate.
- Does the holder of the permit regularly check if the collecting system works properly?
- Check the level of the leachate in the landfill. Are pumps working like they should be? Is the pump set at the bottom of the wells? The leachate collection system must always perform normally to prevent a buildup of leachate in the landfill. If leachate can't be drained from the landfill in some moment in time it will cause problems like instability of the site or groundwater pollution.
- The quality of the leachate should be monitored regularly. The quality of the leachate has to be determined regularly to determine which treatment it needs to re-use it or to determine how it has to be treated before discharging it.
- In case leachate is treated it can be checked if the treatment plant works properly.
- Check the quality of discharged leachate.

Surface water

- Take samples at the discharging points of (treated) leachate and other wastewaters into the surface water to determine if permit regulations are not violated.
- Check if surface water can't enter the landfill.
- Check if all control precautions taken by the holder of the permit are functioning in the right way.

Run-off water

- Check if the run-off water can be collected to prevent it from running uncontrolled into surface water.
- Are ditches or collecting canals built to catch run-off water?
- Is the run-off water collected and checked before discharging?

- Does the run-off collection system foresee a “first flush type” so the more heavily contaminated water is discharged into a sewer?
- Are slopes of the landfill constructed in a way so run-off water flows into the sealed landfill?

8.10. Existing guidelines in Member States

Table 7: Overview of used Guidances in Member States

Organisation	Title of document
UK **Environmental Agency**	Monitoring of landfill leachate, groundwater and surface water and other relevant literature[27]
Sweden **Swedish Environmental Protection Agency**	Landfilling of waste Handbook 2004:2 with guidelines to the Ordinance (2001:512) on the Landfill of Waste and to Chapter 15, 34 § of the Environmental Code (1998:808)
Germany **Factory inspection board of Lower Saxony (Hildesheim)**	**“**Waste Management facts”[28] Abfallwitschaftsfakten Lower Saxony 1.2. Handling leachate in landfill 9.1. Trigger Thresholds an action plans (Groundwater) 21. Draining leachate in free slope 24. Hydraulic calculation, collecting and discharging of non contaminated Rainwater

[27] https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/321602/LFTGN02.pdf

[28] https://www.gewerbeaufsicht.niedersachsen.de/startseite/umweltschutz/kreislauf_und_abfallwirtschaft/abfallwirtschaftsfakten/abfallwirtschaftsfakten-52057.html

9. TOP AND BOTTOM LAYERS: CONSTRUCTION, CLOSING AND AFTERCARE

9.1. Legal requirements

Legal requirements about building and closing phase in a landfill, are set in the Landfill Directive as follows:

BOX 8. Provisions about building and closing phases

Article 8 Conditions of the permit

(c) Prior to 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 13 Closure and after care procedures

(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 for approval for the closure. This shall not in any way reduce the responsibility of the operator under the conditions of the permit.

(c) After landfill has been definitively closed, the operator shall be responsible for its maintenance, monitoring and control in the alter-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.

ANNEX I: General requirements for all classes of Landfills

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 also by the combination of a geological barrier and a top liner during the passive phase/post closure.

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:

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:

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.

6. Stability

The emplacement of waste on the site shall take place in such way as to ensure stability of the mass of the waste and associated structures, particularly in respect of avoidance of slippages. Where an artificial barrier is stablished 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

9.2. Description

The construction of a landfill and its subsequent closure must ensure the dual objective of holding waste safely and not causing any pollution to the environment, both in the operational and closed phases.

The Council Directive 1999/31/EC establishes a requirement to clearly indicate 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 specially against the pollution of groundwater by leachate infiltration into the soil

To obtain a landfill permit the operator has to present, among other documents, a building project that includes at least:

- The engineering design with the submission of construction proposals: constructive solution
- Construction Quality Assurance Plan (QAP) - Supervised by an independent third party (with the agreement of the authority) (UK, Spain, Germany)
- Specifications
- Drawings.

Once permission has been granted, the building phase can start. From this moment the work of inspection begins.

To determine whether a landfill is performing as designed, landfills have to be inspected in the building operating and closing phases.

This requires at least one inspection before the start of activity and another one before the approval of the closure (Article 8 c and 13 c of the Council Directive 1999/31/EC, respectively). Different stages of the building and closing phases shall be inspected.

It should be noted that this is the phase in which it may be verified that all measures to prevent pollution and to ensure safety have been adopted. It is at this time when the existence of the drainage of groundwater, the execution of leachate collection systems, surface water, the inclination of the slopes and has provided the entire package of waterproofing can be verified.

The purpose of the inspections during the building phase is:

- To ensure protection of soil and water (surface and groundwater).
- To ensure stability.
- To check the sealing system, the surface water, groundwater and leachate collection systems and biogas collecting system, if necessary.
- The purpose of the inspections during the closing phase is:
- To verify that the final work of sealing has successfully been executed.
- To ensure that the operator has adopted the necessary measures for the maintenance, monitoring and control of the landfill in the after-care phase, special attention to:
    - Leachate collecting system.
    - Biogas collecting system, if necessary.

9.3. Best practices

Building phase: 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 permits.

Closure phase: 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.

In both building and closing phases, the construction requirements shall be verified by the competent authority. A final report is needed.

The aftercare phase also has to be monitored. Here, the respective special conditions of aftercare for the site must be taken into account. For example, groundwater and surface water monitoring, gas production, quality of surface sealing and planting.

In order to facilitate this work more than one inspection (articles 8 and 13 of Council Directive 1999/31/EC) has to performed, so it is necessary:

- To define the most important stages to inspect during the building and closing phases: two kinds of inspections (several during the building/closing phase and one final inspection at the end of the works) (see preparation of the inspection: desk study).
- To have a great knowledge of the permit: constructive solution, specifications and drawings.
- To perform inspections in the different stages of the building and closing phases.
- To have special training for the inspectors is needed: training plans developed by MS.

9.4. Inspection preparation: desk study

An in-depth knowledge of the permit and also the project details (construction details, specifications, calculations and technical drawings) is needed to be able to perform an inspection. The inspector has to:

- Review permit conditions (IPPC or others) for the construction and management and for landfill closure.
- Collect the construction project documentation.

These are the key topics:

- Description of the excavation work, compaction and conditioning of the base of the landfill.
- Description of groundwater collection systems, if it exists.
- Description of the systems of collection and drain of surface water.
- Description of run-off water collection system.
- Characteristics of bottom sealing and slopes of the landfill.
  - Bottom sealing.
  - Anchoring bottom sealing.
- Description of the systems of collection and treatment of leachate.
- Description of catchment systems and treatment of biogas.
- Type of enclosure to prevent free access to the installation.
- Operating Plan. Works initial operation of the landfill (Protection package landfill background).
- Construction Quality Assurance (CQA) plan for the Construction of lining system.
- The inspector checks the CQA plan of geosynthetics was developed by an independent third party (with national appropriate accreditation).

- The inspector finds that there is a validation report on completion on works to (good execution) conclude that the installation of geosynthetics was completed according to the specifications of CQA plan ensuring that this plan was monitored according to criteria of absolute independence.
- Once executed the plan quality control of geosynthetics and checked the certificate of final work and, if any, changed the construction project, inspection final check of the work will be done before use.

9.5. On site Inspection

Initial inspection

Control of the preparation of suitable land (Morphology landfill). The support surface of geosynthetics.

Preparation of landfill base, normally to be checked as follows:

- Groundwater collection network: check existence, gradient and connections.
- Quality of material: the base material should be regular, with homogenous grain size, without large particles that may cause damage of the HDPE sealing.
- Thickness: rough check possible of raw material, if installed by GPS measures.
- Compaction: a compaction level at bottom of cell and slopes as defined in national regulation will be reached by adequate compaction.
- Flatness and smoothness of surface before installing artificial (HDPE) sealing.

Figure 39: Bottom and slope of the cell

Figure 40: Groundwater collection network

Here a draining system for groundwater water has been installed.
High groundwater levels can cause problems with mineral and also artificial layer (geomembrane).

Figure 41: Keys to control and connections

Intermediate inspections

a. Checking base liner systems[29]:

Waste		
Geotextile filter	Geotextile filter	Composite drainage
Drainage layer (Gravel)	Drainage layer (Gravel)	
Geotextile protection layer	Geotextile protection layer	
Artificial sealing liner (Geomembrane - HDPE)		
Impermeable mineral layer (Geosynthetic clay liners or clay)		

[29] Base liner system model: It complies with Council Directive 1999/31/EC Annex I. May vary, depending on national regulation

Compacted natural ground (drainage of groundwater)	Compacted natural ground
Bottom	Slope

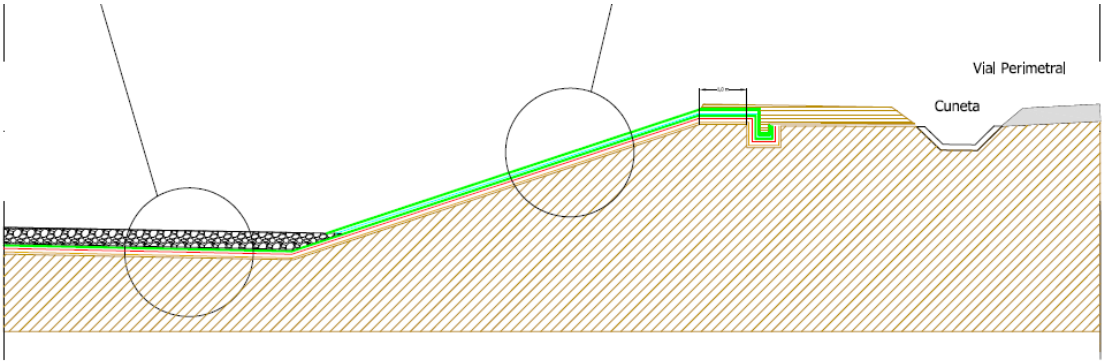

Figure 42: Base liner

b. Checking existence of bottom layers

Figure 43: Bottom layer

c. Checking existence of anchor sheets

Figure 44: Trenches in coronation slope

- Anchor trench, in coronation slope.
- Anchor berm, by overweights.
- Anchor singular elements, by attaching the sheet to the element.

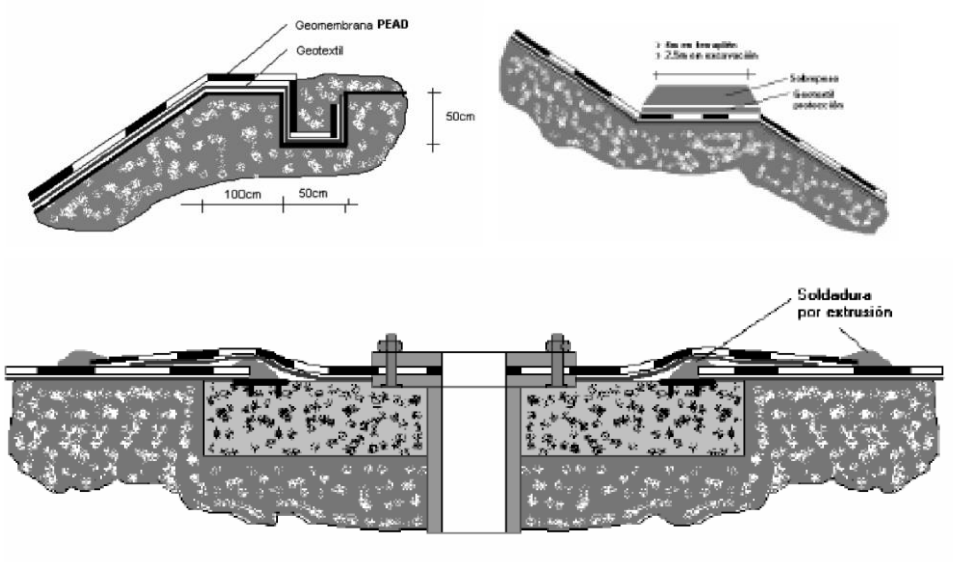

Figure 45: Anchoring systems

d. Mineral layer, checking existence and thickness, roughly determined finally determined by GPS

Figure 46: Clay thickness

Figure 47: Clay layer

e. Geosynthetic clay liners (GCL), checking existence and overlap between panels

Figure 48: Geosynthetic clay liners

f. Geomembrane (HDPE)

Figure 49: Geomembrane

g. Geotextile protection

Figure 50: Geotextile protection

h. Gravel, checking the thickness, roughly determined, finally determined by GPS

Figure 51: Thickness of gravel layer

i. Geotextile filter

Figure 52: Geotextile filter

j. Composite drainage

Exceptions may be granted for the installation of the composite drainage, in this case it is installed with advancing operation.

Figure 53: Preparing the bottom - materials

k. Leachate collection network, checking existence and connections (better avoid penetration of bottom layer where possible).

Figure 54: Leachate collection network

l. Structures in cells to minimize leachate generation can be performed.

Figure 55: Cell construction

Landfill base and embankments should be structured into sections with appropriate slopes to drain off uncontaminated water and to minimize the occurrence of leachate.

Final inspection

Once executed the quality control plan of geosynthetics and checked the certificate of final work, an inspection final check of the work will be done before the start of the operational phase.

Operation system, for example:

a. Extraction systems

Figure 56: Extraction system

b. Access ramp

Figure 57: Access ramp

c. Rainwater collection network, checking existence and connections.

Figure 58: Ditch perimeter of rainwater

- Detailed report of the repairs made.
- Detailed layout sheets welds and patches.

After the start of the operation

After the approval of the competent authority with the work to prompt the operator in monitoring and documenting, through photographic reportage, the start of the operation and placement of geocomposite drainage.

a. Start operating

Figure 59: Operation start

b. Attaching the composite drainage during operation

Figure 60: Attaching the composite drainage

Final report after completion of construction

Landfills are structures that must meet the requirements of European and national landfill and waste legislation, as well as those of the construction law applicable in the member state. Therefore, it must be confirmed for all completed components of a landfill that they comply with the requirements of the permit. Depending on the regulations in the member states, this will take place through:

- acceptance by the competent authorities on the basis of documents prepared by certified experts,
- confirmation by certified assessors, or
- corresponding jointly prepared documents, whereby the final confirmation should always be made by the competent authority.

This applies in principle to all components, such as for example:

- scales
- buildings
- gas collection and treatment plants
- leachate collection and treatment plants
- road construction
- fencing
- possible planting / nature conservation / recultivation
- all works for the construction of the sealing elements for the base and the surface.

10. FINANCIAL GUARANTEES

10.1. Legal requirements

Article 8 of the Landfill Directive requires member states to include conditions in landfill permits to ensure that 'adequate provisions, by way of a financial security or equivalent, have 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 are discharged.

10.2. Description

The determination of financial provision at landfills is intended to ensure that the landfill operator's obligations to prevent and eliminate impairments to the public welfare can also be fulfilled if the operator is not willing or able to comply. The aim is to prevent the public sector from having to vouch for costs that it did not incur.

The financial provision is intended to cover the costs incurred for an orderly operation and closure of the landfill without adversely affecting the public welfare. It is generally difficult to estimate or forecast these costs.

To be effective, financial provision must be:

- secure for the duration of an operator's activities, and, in the event of an operator's insolvency or dissolution, funds must be available to discharge the environmental liabilities;
- sufficient to cover all of the environmental liabilities; and
- available to the relevant person, such as the regulator, to discharge the environmental liabilities when required.

If these conditions are not satisfied, the financial provision may fail. It is essential that the financial provision is established on a sound economic and legal basis in the first place and maintained and monitored thereafter.

Defining the appropriate amount of provision is crucial. If financial provision is secure and available but in an inadequate amount, then the public purse may be required to meet the shortfall, and the process will not be fully successful.

The timing of the availability of the provision is also important. For facilities that are subject to progressive closure, financial provision needs to reflect the partial closure works as well as the final stage of closure, and the period of aftercare. The duration of the aftercare period needs to be determined, with landfill sites typically being considered to require aftercare financial provisions for at least 30 years.

In terms of the legal certainty of the financial provision, one of the most important factors is ensuring that the financial provision is protected in the event of operator insolvency or dissolution, as this is often when it is required. In the case of insolvency the complete amount must be available immediately.

In the case of landfills the closure, restoration and aftercare costs extend over long periods and change over time. Key points throughout the duration of the operation (e.g. initial liability, maximum liability) and the ultimate end date should be established. This pattern of costs can be referred to as the 'cost profile'.

It is necessary for the financial provision to be periodically reviewed by the competent authority with a view to maintaining the real value. This is only practicable on the basis of proper inspection and monitoring. The guarantee must be re-established if the relationship between the security and the intended purpose of the security has changed significantly. If this is the case, the landfill operator may also apply to the competent authority for the security to be reviewed.

The cost profile

The typical costs to be covered at a landfill include:

- Monitoring, e.g. surface water, groundwater, air, gas, leachate, stability.
- Maintenance of monitoring equipment.
- Maintenance of infrastructure.
- Verification and reporting.
- Site security.
- Final capping (incl. all measures for manufacturing all sealing layers).
- Landscaping (incl. maintenance of recultivation layer and vegetation , if permission contains conditions).
- Surface water drainage (incl. surface water retention).
- Leachate and gas infrastructure and management, including leachate disposal.
- Plant decontamination.

Often landfills are built, operated and closed in phases, so the task is to define, which costs belong to the entire landfill and which costs belong to separate sections.

For the typical non-hazardous landfill site the aftercare period could be as long as 60 years. However, the estimated amount of financial provision proposed will be site specific depending on the operational proposals and the scale of the landfill but in all cases they will follow the same form of Financial Profile. This is shown below in the figure with four key amounts over the life of the site.

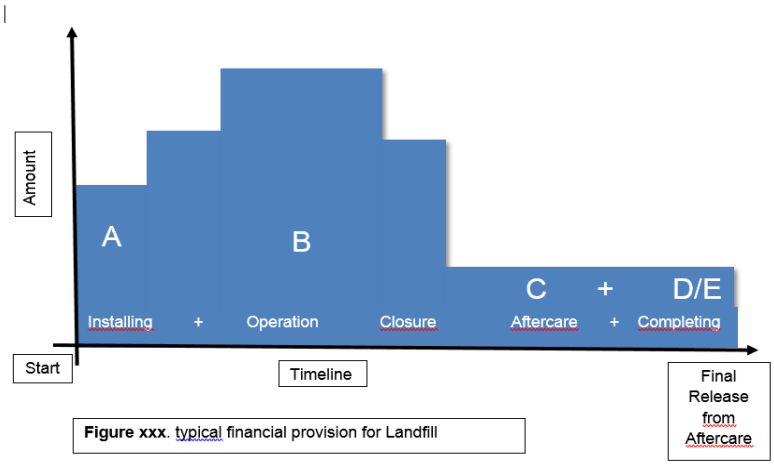

Figure 61: Typical financial provision profile for landfill

Initial Provision:

Estimate A represents the initial sum that will need to be allowed for and included in the maximum amount. This is to cover contingencies should any difficulties be experienced. This could cover for example failure of leachate treatment system, or surface water control, or containment stability failure, leading to flooding in containment cells thus involving expensive removal by tanker. This initial sum must be derived from a site specific risk assessment conducted by the operator, taking into account the proposed scale of operations and an assessment of the risks of failure of environmental controls at the site and the additional estimated cost of contingency operations out with normal foreseen operational costs. This first assessment created by the operator has to be

submitted to the regulator for final assessment and approval. As soon as waste is deposited in a landfill, the costs for surface sealing must be retrievable. Otherwise there would be no funds available in the event of insolvency. So it makes sense to include the costs for surface sealing as soon as a landfill site is created. This concerns either the section or the entire landfill. Maximum Financial Provision:

Estimate B represents the maximum sum that must be accrued to cover the estimated costs of capping, restorations, closure and aftercare through to final surrender of the complete landfill site or a part thereof along with contingency costs. This again must be derived on a site specific basis by the operator taking into account the proposed scale of operations, the estimated after-care period, the long term risk of the site and be related to the design leachate emission and gas production risk assessments and operational proposals for the specific landfill in question.

Commencement of passive after-care period:

Estimate C represents a break point in the rate of after-care expenditure when active controls at the site cease. This is likely to be many decades for a biodegradable landfill whilst may be only a few years for an inert landfill. At this point, although emissions are at a level where specific active controls (i.e. leachate abstraction, gas collection) are now not required, the site is still not in a condition where the permit can be surrendered. The rate of expenditure then slows as activities primarily relate to monitoring of the site and its environs.

Surrender Contingency:

Estimate D represents a contingency sum to be included to account for the surrender stage. This should include any decommissioning or final site clearance works and also an amount to reflect the uncertainty that the permit can be surrendered after the estimated after-care period (e.g. 60 years from end of disposal). This should allow for an additional period of monitoring, at a further reduced frequency until surrender conditions can be satisfied. Where operators propose that their non-hazardous site is going to reach surrender status in less than 60 years the contingency sum should be increased to reflect the increased risk that this aspirational aim may not be achieved.

Completing Phase

At the end of the aftercare phase, there are even greater costs for completing this phase e.g.

- Determination of the functionality of the sealing systems
- Determination of the functionality of remaining technical equipment like:
  - Drainage ditches
  - Retention basin
  - Discharge structures for surface water
  - Paths and paved areas
- Dismantling of structural facilities like:
  - Buildings
  - Landfill routes
  - Traffic areas
  - Power plant, gas treatment plant
  - Leachate treatment plant
- Dismantling of the measuring equipment like:

- Groundwater monitoring wells
- Leachate measuring points
- Surface water measuring points
- weather station
- Settlement measuring points

- Dismantling of other technical facilities:
  - Gas wells and collecting system
  - Leachate pipes and pumps (deconstruction or damming)
  - Fence system

10.3. Best practice

Depending on the national legislation in the member states, different approaches can be followed.

Scotland

The estimated amount of financial provision is established and proposed by the operator based on a full life cycle costing of the technical measures specific to the site. A financial provision submission should comprise a year by year profile of estimated total costs supported by detailed, costed breakdown of the individual components.

Two stages are required when checking the amount of financial provision:

1. The first stage is to check that the breakdown of items is sufficiently detailed such that the key components/activities can be identified and compared with the operational practices proposed at the site and covered by the landfill permit.
2. The second stage is to check that the costs associated with the key components (gas management, leachate management and monitoring) and the overall amounts of financial provision are reasonable.

This first assessment created by the operator has to be submitted to the regulator for final assessment and approval.

Germany

a) Landfilling phase

The requirements and conditions for preventing or eliminating impairments to the public welfare, which relate to the landfilling phase, should have been implemented before the start of this phase. These are in particular the manufacture of a basic sealing system and facilities for the collection and treatment of landfill gas and leachate. The remaining requirements relating to the landfilling operation should be able to be covered from the income that the landfill operator achieves with landfilling. In this respect, the landfilling phase appears to be of subordinate importance for the determination of a security deposit.

b) Closure and aftercare

A significant part of the costs are related to the manufacture of the surface sealing system. It must be taken into account that the costs specified here are subject to strong economic fluctuations and a continuous price increase. Regional deviations due to the different availability of certain building materials (e.g. clay) can also influence the budget. If the landfill operator's calculations include

components for which it is estimated that lower costs are incurred due to the operator's own services, it must be taken into account that in the event of insolvency, these own contributions are not available. Accordingly, current market prices have to be used instead. The same applies to building materials that are already held by the landfill operator and therefore do not appear in the calculation of the provisions. In the event of insolvency, such materials are not available to the construction company if they can be sold by the insolvency administrator

Normally a regularly operated aftercare is to be assumed. A complex remediation or dismantling of the landfill, which will be determined later, is not to be taken into account.

The duration of the aftercare phase has a significant impact on the costs of aftercare. Therefore essential to predict the duration of the aftercare phase on the basis of the available knowledge about landfill behavior.

For an assessment of duration of the aftercare, it is advisable to analyze the development of the amount and quality of

- Leachate
- Landfill Gas

and to make a forecast. Only when treatment of leachate and gas is not required any longer, the end of the aftercare phase can be determined.

A different approach is taken if landfills are owned and operated by public institutions like cities or districts than by private companies. Because public institutions are unlikely to become insolvent the financial provision may be reduced or can be waived.

Existing guideline

Germany State Agency for Nature, Environment and Consumer Protection North Rhine-Westphalia	The provision of security for landfills[30] Assistance to competent authorities LANUV Worksheet 49 2020

Italy

The application for authorization of a landfill must be accompanied by two guarantees:

- One for the activation and operational management of the landfill. This guarantee ensures compliance with the provisions contained in the authorization and must be maintained for at least 2 years from the date on which the competent territorial authority (currently the Regions) notifies the operator of the approval of the landfill closure;
- One for the management following the closure of the landfill. This guarantee ensures that the management procedures prescribed by Article 13 of the decree are carried out and must have a duration of at least 30 years from the date of landfill closure.

The guarantees may alternatively be constituted by:

- a valid real bond;
- a bank guarantee;
- an insurance policy linked to the insurance sector.

[30] www.lanuv.nrw.de

10.4. Principal types of financial provision for landfill

The interpretation, verification, and monitoring of the financial provision is time consuming and expensive, and also requires financial expertise. Depending on different regulations in the Member States various types of financial guarantees are to be accepted. The following listing gives an overview without any right of completeness.

Financial Institution Guarantee

A financial institution guarantee is a guarantee provided by a financial institution (e.g. a bank or surety) to pay if an operator defaults on its obligations. This includes 'bank guarantees' and 'letters of credit', 'surety bonds' and 'performance bonds'. Issuance of a guarantee by a financial institution is generally supported by the payment of a premium and/or through the deposit of cash, securities or other assets for all, or a percentage of, the value of the guarantee. If the operator defaults on its obligations to the regulator, the financial institution pays or performs according to the contractual arrangements instead of the operator up to the amount of the guarantee.

Parent company guarantee

A parent company guarantee is a legally binding guarantee by an operator's parent company (or another affiliate) to pay or satisfy the operator's environmental obligations if the operator fails to do so. It is often limited to a specified amount (i.e. an unlimited guarantee may not be given.)

The particular risk with parent company guarantees, is that the guarantee could become devalued or worthless if the financial strength of the parent/group declined alongside that of the operator, the worst case being simultaneous insolvency or dissolution.

Cash deposit

A cash deposit is money deposited by an operator with a third party (e.g. in a bank account) and legally secured so that it can only be used for the intended purposes. This includes 'escrow accounts'.

An escrow account is a sum of money deposited in a dedicated account with a third party, usually a financial institution, on account of an obligation owed by the regulated person to a regulator. The third party agrees to pay out the money according to the terms of the documentation establishing the account, usually directly to the regulator on presentation of specified documentation.

In certain circumstances, a regulator may consider allowing an operator to build up the fund over an agreed period of time. While the fund is building up, the operator should put in place an appropriate alternative financial provision.

Mutual Fund/Pool

A mutual fund/pool is a mechanism by which a group of operators may satisfy financial provision requirements by demonstrating their membership of it. Acceptance into the mutual fund/pool requires the members to provide evidence of a specified amount of financial provision, and/or to pay a specified amount into the fund/pool each year. Members must agree to pay up to a specified (or unspecified) amount if a member of the fund/pool fails to do so. If the amount of such payment exceeds the monies held by the fund/pool, an additional drawing may be made on the members.

Charge on asset

A charge on asset may take the form of a charge on premises (i.e. real estate) or other assets owned by an operator.

A charge on premises may take the form of a first ranking mortgage/fixed charge over a specific piece of land or real estate in favour of the regulator. While the land/real estate remains in the possession of the operator, the regulator will have the legal right to enforce their security over the asset and exercise their power of sale in respect of it if the operator fails to meet its obligations to the regulator or there is any other 'event of default' under the charge. This could, for example, include operator insolvency or dissolution under domestic law.

Self-provision

Self-provision is financial provision by the operator itself.

Self-provision is the weakest method of financial provision. This may only amount to ensuring the operator plans for environmental liabilities, represents environmental liabilities in financial statements and/or provides a written commitment. Although it may be supported by financial criteria and checks, self-provision still offers little or no protection in the event of operator insolvency or dissolution. If the regulator becomes aware of the deteriorating financial strength of the operator and requires it to deposit funds or assets to provide for environmental liabilities, then this may be challenged under domestic insolvency or winding up law as a 'preference'.

10.5. Monitoring and enforcement

Following the establishment of the specific form of financial provision, ongoing maintenance and monitoring of the financial provision during the lifetime of the operation is necessary. This may be as simple as ensuring that financial provision, such as an insurance or guarantee, is renewed or it may involve a more in-depth investigation as to whether the operator continues to satisfy the financial tests.

Practices that should be considered by regulators for checking and monitoring each of the different types of financial provision are detailed below. Before considering these, two more general points applicable to all the measures covered below may be made:

1. The operator could, if they are not so already, be placed under an obligation to inform the regulator of any material change in their financial strength or petition being presented, or resolution being passed, to wind up the company. This would give the regulator advance notice of any entry of the operator, or potential entry, into insolvency or winding up proceedings.
2. Regulators should have a clear, pre-prepared plan of action should the operator or their parent company no longer be in a position to deliver the financial provision that they originally presented. For instance, a plan should be in place as to the appropriate course of action should a self-insuring operator, or a parent company that provides a parent company guarantee, be no longer able to meet the financial tests.

Financial institution guarantee

- The regulator may want to conduct ongoing health checks of the financial institution.
- The performance agreement associated with any guarantee should contain a clause requiring the operator to renew it prior to the expiry.
- A renewable guarantee may require a fixed sum to be paid from day one, or it may be incremental, building up or decreasing year by year as the liability on the site increases or decreases. In either case, the sum should be subject to an annual inflationary adjustment as specified in the relevant clause in the performance agreement.

Parent company guarantee and self-provision

- Regular ongoing monitoring of the financial strength of the operator and/or their parent company typically based on detailed, specified financial criteria. The financial criteria may include net assets and net current assets, location of assets, various financial ratios. The operator or parent could be required to continue to meet a specified credit rating which must be reported direct to the regulator at the cost of the operator.

Cash deposits

- The regulator should review the deposits regularly (at least annually) to ensure that the sums deposited accord with the expenditure profile. The sum should be subject to an annual

inflationary adjustment which should be specified in the relevant clause in the performance agreement. The regulator should carry out this calculation and communicate it to the operator.

- If the operator wishes to withdraw sums for works legitimately carried out under the permit, they should be requested to present contractors' invoices as evidence.
- It is vital that account statements are issued to both parties on a regular basis. The regulator should review the statements to ensure that the value of the deposit is in line with the agreed profile.

Mutual fund/pool

- Monitor information provided on a rolling/regular basis as to the financial viability of members or delegate this task.
- Monitor membership and any financial provision evidenced by them to improve the ability to respond quickly to any negative changes or delegate this task.
- Investigate notification of any: incidents or events that affect the financial viability of the fund/pool, e.g. reductions in members' credit ratings, insolvencies.

Charge on asset

- The charge instrument may provide that a breach of the required 'property value : financial provision' ratio will entitle the regulator to exercise their power of sale under the charge. The operator should accordingly be required to periodically provide an independent valuation of the property to the regulator to demonstrate that the 'property value : financial provision' ratio continues to be satisfied.
- Monitor any requirement that the operator maintain appropriate insurance in respect of the property subject to the charge.
-

Enforcement

Regulators need to have systems and protocols in place to respond decisively and effectively to the following types of scenarios.

- Making a demand on the financial provision if the event arises, e.g. in the event of insolvency or dissolution of the operator leading to abandoned closure liabilities or an incident leading to environmental pollution.
- Failure to maintain financial provision, e.g. non-renewal of insurances or guarantees.
- Failure to maintain membership of a mutual fund/pool.
- Failure to increase financial provision in line with increasing liability.
- Failure to make scheduled payments into cash deposits.
- Declining financial health of operator or parent.
- Declining value of an asset.

The options available to regulators will depend on the legal systems in place in that country but, as with any other matter of environmental enforcement, there should be provision for administrative or legal sanction.

11. LANDFILL OPERATOR SELF MONITORING AND ANNUAL REPORT

11.1. Legal requirements

Landfill Directive

A landfill management permit includes 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 of the Directive 1999/31 on the Landfill of waste.

Landfill operator self-monitoring Plan is therefore an integrative part of the landfill management permit and it relates both to the operational and post-operational management phase.

Minimum requirements of the self-monitoring Plan are set in Annex III “Control and monitoring procedures in operation and after-care Phases” of the Landfill Directive.

Industrial Emission Directive

According to the Industrial Emission Directive, ‘environmental inspection’ includes verification of self-monitoring. Suitable emission monitoring requirements specifying measurement methodology, frequency and evaluation procedure should be included in a IED permit.

Furthermore, the IED Directive sets an obligation to supply the competent authority regularly, and at least annually, with information on the basis of results of emission and other required data that enables the competent authority to verify compliance with the permit conditions.

E-PRTR

Another important module of monitoring is the European Pollutant Release and Transfer Register, (E-PRTR)[31] This is the Europe-wide register that provides easily accessible key environmental data from industrial facilities (also Landfills) in European Union Member States and in Iceland, Liechtenstein and Norway. The E-PRTR has to be filled in by the operator, checked by the authority. Since 2009, Member States have been required to annually publish data on releases to air, water, soil, as well as data on transfers of pollutants contained in wastewater and waste disposal on the publicly accessible website. The PRTR aims to provide public access to environmental information and thus ensure public participation in environmental decision-making, as well as to promote the improvement of companies' environmental performance in the long term.

The EPRTR has been replaced by the Industrial Emissions Portal Regulation (IEPR), which was adopted on 12 April 2024 and entered into force on 22 May 2024. During the following two years, the Commission will work on implementing rules. The first data reported under the new law and describing releases and resource use in 2027 will be published in 2028.

11.2. Description

According to the Landfill Directive, the purpose of the self-monitoring plan 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

[31] https://industry.eea.europa.eu/#/home

- that the environmental protection systems are functioning fully as intended
- that the permit conditions for the landfill are fulfilled.

The self-monitoring plan should consist of a combination of:

- administrative records, technical and management checks;
- continuous measurements if necessary (e.g. piezometric level measurements of parameters measured by multiparameter probes);
- discontinuous measurements (periodically repeated systematically)

It should at least contain provisions for the following aspects:

- Meteorological data
- Emission data: water, leachate and gas control
- Protection of groundwater
- Topography of the site: data on the landfill body
- Specific requirements for metallic mercury.

The proposal as reported in Annex 4, which includes the minimum requirements of monitoring actions as indicated in the Landfill Directive, incorporates a combination of required process data (including consumptions) and analytical measures, in order to build a complete picture of the performance of the landfill. The provided general indications will have to be adapted and evaluated on the basis of the characteristics of the landfill.

These results should be included in the self-monitoring Report, namely the document including the monitoring results which the operator has to send to the competent authority, usually on a yearly basis.

ANNEX 1: DESK STUDY CHECKLIST - INSPECTION PREPARATION

To have an in-depth knowledge about the landfill is the most important condition for the successful preparation of the inspection.

This Annex gives an overview of the different documents to study according to the type of landfill to inspect and the purpose of the inspection.

The key documents to study posted below are listed in three categories:

1. Revision of documents (first approach)

    1.a) Permit review of imposed conditional on authorization (IPPC or others)
    1.b) Specific conditions (3.1-3.6)
    1.c) Project
    1.d) Drawings
    1.e) Environmental monitoring plan (EMP)
    1.f) Results of the environmental monitoring plan

2. Deeper analysis of the documents (depending on the type of inspection)

    2.a) Waste acceptance criteria: depending on the type of landfill (hazardous, non-hazardous, inert)
    2.b) Systems of collection of gas, if relevant.
    2.c) Systems of collection and drain of surface water.
    2.d) Systems of collecting groundwater, if relevant.
    2.f) Systems of collection and treatment of leachate
    2.f) Building phase and closure phase (Bottom sealing, anchoring, Construction Quality assurance -CQA- ecc.)

3. Other documents (accidents, incidents and complaints)

    3.a) Gathering all the information about the accident/incident/complaints
    3.b) Which activity of the landfill (3.1-3.6) *is the accident/incident/complaint connected with?*
    3.c) Review of the documents related with the accident/incident/complaint

Example: Regular unnnounced inspection (inspection plan). Focus on leachate water and biogas.

		Desk Study (documents to review)														
Type of inspection:		**1. Revision of documents (first approach)**						**2.. Revision of documents (deeper analysis)**						**3. Others documents)**		
		1.a)	1.b)	1.c)	1.d)	1.e)	1.f)	2.a)	2.b)	2.c)	2.d)	2.e)	2.f)	3.a)	3.b)	3.c)
Initial		X	X	X	X	X	X									
	Pre-operational															
Regular																
	Announced on-site inspection															
	Unannounced inspection (following an inspection plan)								X		X		X			
Others																
	Accidents															
	Incident															
	Complaints															

ANNEX 2: CHECKLIST ON-SITE INSPECTION

The following checklist has to be reviewd and amended according to the national legislation in place

GENERAL DATA

Date of inspection:	
Inspection type:	*Routine or non-routine environmental inspections*
Installation:	
Address:	
IPPC category:	
n. of permit:	
IPPC referent:	
E-mail:	
Phone number:	

TYPE OF LANDFILL	
Hazardous waste	☐
Non-hazardous waste (these landfills may be used for (i) municipal waste (ii) non-hazardous waste of any origin, which fulfil the criteria for the acceptance of waste at landfill for non-hazardous waste set out in accordance with annex II (and Council decision 2002/33/EC) iii) stable, non-reactive hazardous waste (e.g. solidified, vitrified) with leaching behaviour equivalent to those of the non-hazardous waste referred to in point (ii) which fulfil the relevant acceptance criteria set out in accordance with Annex II (and Council decision 2002/33/EC). These hazardous waste shall not be deposited in cells destined for biodegradable non-hazardous waste)	☐
Inert waste	☐

Tab. A - GENERAL ELEMENTS OF COMPANY MANAGEMENT				
Aspect Verified	**Legal reference[32]**	**Findings**	**Documents to request**	**What to verify**
Presentation of the facility by the operator through layout and drawings	-			Verify the compliance of the authorized setup with what is described by the operator and observed in the field
Environmental policy management	-			Verify the existence of a company organizational chart defining roles in environmental policy management: organizational chart, specific delegations, and assigned responsibilities.
Environmental Management System (EMS)	BAT			Verify the existence and validity of any environmental certifications (ISO 14000, EMAS). Randomly check some procedures of the Environmental Management System (EMS) through interviews with the operators
				Verify the existence and validity of any environmental certifications (ISO 14000, EMAS). Randomly check some procedures of the Environmental Management System (EMS) through interviews with the operators
Operational management plans, environmental restoration plans, post-operational management plans				Verify whether the plans have been updated following any modifications and if the operational management plan is integrated into the EMS
Emergency response plan for extraordinary conditions				Check in the EMS and the Operational Management Plan for the presence of an emergency response plan for extraordinary conditions such as: ▪ flooding;

[32] Reference to permit provisions or law requirements

Tab. A - GENERAL ELEMENTS OF COMPANY MANAGEMENT				
Aspect Verified	**Legal reference[32]**	**Findings**	**Documents to request**	**What to verify**
				▪ fires; ▪ explosions; ▪ reaching trigger levels of contamination indicators; ▪ accidental waste dispersal into the environment
				Verify the adoption of written operational practices for managing emergencies caused by malfunctions of the leachate extraction system or biogas extraction system.
				Conduct interviews with operators to ensure their knowledge and correct application of the procedures
Training and education of operators involved in environmental management				Verify the presence of specific records documenting the frequency and type of training and professional and technical education courses for the plant personnel. Staff assigned to emergency interventions must be instructed and informed in advance about emergency response techniques
Maintenance and plant operation log				Check the interventions carried out to ensure routine and extraordinary maintenance of all functional structures and systems of the landfill.
				Verify the existence of a plant log where routine and extraordinary maintenance activities are recorded, as well as any malfunctions or failures in the leachate extraction line and the weather monitoring station, along with the outcomes and dates of calibrations, etc.

Tab. B – WASTE ACCEPTANCE CRITERIA (see also Annex 3)				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
Treatment				Request the EMS provisions regarding the assessment of the need for treatment of incoming waste. Identify some EER codes among the incoming waste streams and verify the execution of preliminary treatment or, if applicable, the reasons for its non-necessity.
Basic characterization				Randomly verify for some waste types (refer to the EER codes authorized in the permit) the maintenance of the basic characterization after confirming whether the waste is generated regularly or not from a production process (with a frequency not exceeding one year or for each batch).
				Randomly check for some waste types the completeness of the information on the basic characterization of the waste received, including: - critical parameters - description of the treatment or a report on the non-necessity of treatment - hazardous properties - assessment of the possibility of recycling/recovery - analytical characterization
				Ensure that the laboratories performing the analyses are accredited (ISO 17025). Randomly verify for some waste types that sampling and analyses are conducted using the proper methods (Section 3 of the 2003/33/EC: Council Decision of 19 December 2002) , including the presence of a sampling plan.
				Verify compliance with the concentration limits in the leaching test

Tab. B – WASTE ACCEPTANCE CRITERIA (see also Annex 3)				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
				Check that the data related to the test results are retained for the period indicated in the permit
Compliance testing				Randomly verify for some waste types that Compliance testing has been conducted and that sampling and analysis methods are being followed.
				Randomly verify for some waste types that the Compliance testing includes at least one leaching test and is based on the data provided by the producer following the basic characterization. Compliance testing shall be carried out at least once a year
				Check that the data related to the test results are retained for the period indicated in the permit
				Ensure that the laboratories performing the analyses are accredited (ISO 17025). Randomly verify for some waste types that sampling and analyses are conducted using the proper methods (Section 3 of the 2003/33/EC: Council Decision of 19 December 2002) , including the presence of a sampling plan.
				Verify compliance with the concentration limits in the leaching test
On-site verification				Randomly check that, upon delivery, samples have been taken periodically and retained for a period determined in the permit (not less than one month Conduct an interview with an operator regarding the procedure followed.

Tab. B – WASTE ACCEPTANCE CRITERIA (see also Annex 3)				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
				In case of the presence of vehicles during the inspection, verify the following: - The reliability of the waste acceptance system, also referencing any available manuals or management procedures. - The presence of an operator to ensure a visual inspection of each waste load before and after unloading by an operator. - The conformity of the unloaded waste with the accompanying form, paying particular attention to the transport start and arrival dates of the waste. - The completion of a check on the documentation certifying that the waste meets the acceptance criteria. - The authorization of the transporter.
Stable non-reactive waste				Randomly verify for some non-reactive stable hazardous waste upon entry the presence of preliminary treatment or sufficient justification for the absence of treatment.
				Randomly verify for some non-reactive stable hazardous waste upon entry the execution of the tests specified in paragraph 2.3 of the Council Decision of 19 December 2002 (leachate test, ANC, stability ecc)
Waste not accepted				Request the provisions of the Environmental Management System (EMS) regarding the verification of the presence of substances not permitted in the waste, as related to Article 5 of the Landfill Directive Specifically verify the presence of whole used tires..
Mirror code waste				In the case of mirror EER codes accepted at the landfill, certificates of non-hazardousness for the waste must be obtained. The analytical reports should clearly outline the logical and analytical process followed for the correct classification of the waste (including threshold values, choice of compounds, etc.).

Tab. C – WASTE DISPOSAL: METHODS AND CULTIVATION CRITERIA				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
Pulverulent waste				Verify the absence of diffuse emissions (odors and dust) during the landfilling phases.
Surface coverage of landfilled waste				Check the effectiveness of the daily coverage of waste that could lead to dust dispersion or unpleasant and harmful emissions.
				Verify the type and origin of the material used for daily coverage. Request the availability of chemical analyses of the soil if the origin is uncertain and a declaration of conformity.
Derogations				In the case of derogations granted under Decision 2003/33, verify the leachate and groundwater data concerning the parameters for which the derogation was granted. Check the quantities related to the EER code for which the derogation was granted. Verify the continued validity of the conditions under which the derogation was granted.
Waste consisting of mineral fibres				Ensure that waste containing mineral fibres is stored in specially and exclusively dedicated cells.
				Check that the cultivated cells are spaced so as to allow the passage of vehicles.
				Ensure that the waste is covered daily with suitable material of plastic consistency.
Asbestos or asbestos-containing waste				Ensure that the storage of asbestos-containing waste (and in particular EER 170605) takes place in dedicated mono cells.
				Check that the cultivated cells are spaced so as to allow the passage of vehicles.
				Ensure that the waste is covered daily with appropriate material of plastic

Tab. C – WASTE DISPOSAL: METHODS AND CULTIVATION CRITERIA				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
				consistency and with a layer at least 20 cm thick.
				Check for a map showing the location of asbestos-containing waste.
Hazardous waste in non-hazardous landfill				Ensure that hazardous waste is deposited in appropriate sectors, cells or trenches of the landfill site, identified by appropriate signage indicating the types and hazardous characteristics of the waste disposed of in each of these sectors, cells or trenches.
Stability and cultivation				Check for any landslides in place and any subsidence due to settling of waste.
				Check the EMS procedure or operational management plan relating to the cultivation mode.
Pest extermination				Verify the implementation and frequency of adequate pest and rodent control campaigns.

Tab. D – WATER AND LEACHATE CONTROL				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
Checking the condition of the drainage and leachate collection system				Verify the system for verifying the minimisation of the leachate head at the bottom of the landfill. Check whether the well is located below the drainage network and whether there is a pump that is automatically triggered

Tab. D – WATER AND LEACHATE CONTROL				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
				Check points where leachate is discharged from the site. Check whether the leachate collection system can be inspected
				Check the condition of the pumping and drainage system (visual inspection and check for any anomalies in the production trend).
				Ensure that the operation of the leachate extraction system is guaranteed even in the event of a power failure by activating emergency generators.
				Check whether leachate (or post-treatment concentrate) is recirculated in the landfill body
				Check the correct treatment and disposal of leachate (preferably to be treated on site) and the presence of storage tanks.
Leachate monitoring				Is the volume and composition monitored at the discharge points? When was the flowmeter last calibrated?
				What is the frequency of monitoring volume (at least monthly) and composition (at least quarterly) ?
				Which parameters are analysed?
				What is the average composition of the leachate and is this in agreement with permit conditions? How is the composition of the leachate checked in relation with the permit.
				Is it necessary to treat the leachate before discharging?
Rainwater drainage				Ensure that rainwater is intercepted by suitable gutters sized on the basis of the

Tab. D – WATER AND LEACHATE CONTROL				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
				heaviest rainfall with a return time of 10 years
				Verification that cultivation and management techniques are used to minimise water infiltration into the waste mass
				Check the state of maintenance and cleanliness of the guttering and the possible presence of stagnation.
Surface water				Check how surface water is prevented from entering into the landfilled waste (when this is required according to the permit). Check also that leachate is prevented from entering the surface water.
				Check if the surface water is monitored at least at two points: - upstream from the landfill - downstream from the landfill
				What are the parameters analyzed?
Water-saving measures	BAT			Check whether special water-saving measures are taken.

Tab. E - SOIL AND WATER PROTECTION				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
Trucks washing waters				Check the presence and use of the washing platform for outgoing vehicles.
				Verify the treatment and discharge of washing water from own and third-party outgoing vehicles.
Waste storage areas	BAT			Check the state of maintenance of the pavements in the areas affected by the handling, storage and operational stops of vehicles.
				Ensure that the areas used for the storage of waste are adequately marked in order to make the nature and hazardousness of the waste known, and that signs are put up showing the rules of conduct for the personnel involved in storage operations.
				Ensure that these areas are properly protected from the action of rainwater and that they are properly managed.
				Ensure that waste containers are appropriately marked with labels or plates bearing the identification code to be used for filling in the loading and unloading registers.
Groundwater trigger levels				Verify that trigger levels have been defined for the various pollutants.
				Check the operational actions to be implemented in case of exceedance of the trigger levels. Is there an action plan available when the trigger levels are exceeded?
Piezometers				Check the technical construction characteristics of the piezometer and in particular: - that are large enough to allow sampling (diameter of at least 4'', or approximately 10 cm);

Tab. E - SOIL AND WATER PROTECTION				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
				- that are clearly identifiable and traceable on the ground; - that they are dimensioned (in m above sea level) and topographically positioned and georeferenced; - have a screw-on or press-on closure cap and be protected by a metal manhole cover, which in turn must be padlocked; - that they have an identification plate (bearing the main information, such as the name of the well, provincial identification code, altitude in metres above sea level);
Groundwater monitoring				Monitoring of groundwater - Parameters analysed in the groundwater - Frequency of analysing groundwater composition
				Check one or several document/s from this year to ensure compliance with the demands of monitoring.
				Check that a campaign of groundwater monitoring is performed before operating in the new landfill. Take a sample of groundwater.
				Is it necessary to prevent groundwater from entering into the land filled waste: does the permit require this?

Tab. F - GAS CONTROL				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
Gas extraction system and monitoring				Check the quantities extracted against those expected.
				Self monitoring results – trends for each of the wells (flux and composition). Biogas flow rate, composition and Energy production registration. Check flow rate, pressure, temperature and monitor inlet gases. Equipment installed reflects the approved design? Check O_2 % - High O_2 implies a leaking system or over-extraction.
Gas flaring torch				Check that the biogas combustion torch was kept lit at all times. Check the operating parameters: temperature (>850°C), O_2 residence time. In case it is switched off, identify the reasons (technical problems, voluntary interception of the pipeline, etc.).
				Check the destination of condensation water.
Energy use				Check whether the quantities of biogas produced justify energy utilisation (flow rate > 100 Nm^3 /h)
Diffuse emissions; biogas capture system efficiency				Check whether the surface of the landfill has been investigated (diffuse emissions) to identify areas not captured by biogas (landfills with biodegradable waste). Check whether diffuse emission analyses have been carried out outside the landfill site
Gas trigger level				Check if trigger levels of biogas in the soil and subsoil have been defined. Check if a risk assessment has been performed to identify measures to be implemented in case of exceedance of the trigger levels.
Observation during inspections				Did you observe indications of gas leaking (for example cracks in slopes on the landfill), odour or vegetation damage?

Tab. F - GAS CONTROL				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
				Register of maintenance of biogas system and safety measures.

TAB. G - PHYSICAL PROTECTION OF INSTALLATIONS, DISTURBANCES AND RISKS				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
Accessibility and protection of the landfill site				Ensure that the landfill site is fenced to prevent free access to the site by people and animals and that the gates are closed outside operating hours.
				Ensure that the landfill is identified by appropriate signage.
Risks				Check for the presence of the following nuisances and risks and any measures taken to minimise them, originating from the landfill and caused by: - odour emission; - dust production; - windblown materials; - noise and traffic; - birds, pests and insects; - aerosol formation.
Dust generation during waste delivery and unloading operations				Ensure that there are procedures to minimise the dispersion of dust and odours. Check the presence of irrigation systems to be used on pulverulent waste dumps
				Ensure that there is adequate irrigation of the access track for the delivery vehicles in order to avoid the emission of dust.
				Carry out a visual check in case trucks are present during unloading.

TAB. H - MONITORING AND CONTROL PLAN: VERIFICATION OF THE REGULARITY OF CONTROLS BY THE OPERATOR				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
Self-control measures: general requirements				Verify that the measurements performed, measurement methods and frequencies are those indicated in the Self Monitoring Plan.
				Check, on a random basis, for exceedances of regulatory limits and data trends.
				Verify that the operator has notified the Competent Authority of any exceedance of self-monitoring measures.
Analytical verifications	PMC			Carry out analytical tests if required.

SPECIFIC CHECKLIST FOR LANDFILL UNDER CONSTRUCTION

Initial inspection	**YES**	**NOT**	**DOESN´T APPLY**	**OBSERVATION**
Control of the preparation of suitable land (Morphology landfill)				
Technicians have given approval to the supporting surface?				
Is it regular and uniform?				
Is it compacted?				

Checking the inner slope of the cell, according to the project				
Groundwater collection network, if any, checking existence and connections.				
There has been a drainage system and channeling the water table?				
Is it installed?				
Is it connected?				
Extraction by gravity				
Extraction by pump				
Control of rainwater during construction				
Are spillages of sewage taking place for the works?				
Is it necessary to construct a settling pond?				
Is it necessary to pave the roads?				
Soil and stone excavation				
Complies with the provisions of the project construction				
Check how they have been managed: reuse as by-product, recycled or landfilled				

Intermediate inspections	**YES**	**NOT**	**DOESN´T APPLY**	**OBSERVATION**
Checking base liner systems:				
- Checking existence of bottom layers				
- Checking existence of anchor trench				
- Clay, checking existence				
- Geosynthetic clay liners (GCL), checking existence and overlap				
- Geomembrane (HDPE)				
- Geotextile protection				
- Gravel, checking the thickness				
- Geotextile filter				
- Composite drainage				
Exceptions may be granted for the installation of the composite drainage in slopes, in this case the geotextile is installed with advancing operation.				

- Leachate collection network, checking existence and connections.				
Is it installed?				
Is it connected?				
Extraction by gravity				
Extraction by pump				
- Have separate systems been implemented for collection of waste water and clean water?				
Were they in the original plans?				

Final inspection	**YES**	**NOT**	**DOESN´T APPLY**	**OBSERVATION**
Check the execution of the Quality Control Plan for geosynthetics and the work completion certificate. Check if any change of the construction project occurred.				
- Operation system.				
Access ramp or other system				
Are extraction systems executed (Groundwater, Leacheate, Biogas)				
- Connecting the networks to endpoint				
- Are treatment systems or disposal described in the project executed?				
Groundwater Ensure that a groundwater monitoring campaign is carried out prior to plant start-up. Carry out a groundwater sampling in the presence of the landfill operator (initial reference blank).				
Leachate (Ponds, reservoirs, treatment systems)				
Leachates are stored so they do not mix with rainwater?				
Where are leachate sample taken?				
Biogas (Degassing chimneys, torch, recovery of biogas)				
Rainwater				
- Rainwater collection network, checking existence and connections.				
Is it installed?				

Is it connected?				
Extraction by gravity				
Extraction by pump				
- Bookmark with GPS elevation vessel background and points infrastructure connections.				
- Detailed report of the repairs made				

CHECKLIST FOR LANDFILL IN THE CLOSING PHASE				
Aspect Verified	**Legal reference**	**Findings**	**Documents to request**	**What to verify**
Temporary and permanent covers				Verify the readiness of the final roofing system within 2 years after the last handover (36 months for completion). Check that after a settlement of less than 5 per cent, the procedures for closing the landfill are activated.
				Checking the length of time a provisional cover is maintained in place of the definitive cover (for the time required to achieve mechanical and biological stability conditions)
				Check for erosive phenomena and localised subsidence in the final and temporary surface. Check the state of maintenance in order to allow the regular flow of runoff water and to minimise its infiltration into the landfill
				Verification of the final covers against what is stated in the Environmental Restoration Plan and the content of the permit.
Monitoring and control				Verify the contents of the aftercare plan with particular reference to system efficiency, monitoring, environmental restoration, and extraordinary conditions.
				Verification of the execution of maintenance, surveillance and controls of the landfill in the post management phase. In particular, verify that biogas, leachate and groundwater checks and analyses are ensured.

ANNEX 3: DETAILED CHECKLIST ON WASTE ACCEPTANCE (EXAMPLE)

WASTE ACCEPTANCE CRITERIA: Selected waste streams to be supervised		
Method of inspection can be to make a selection of the different types of waste streams that the landfill may accept according to the permit. For the streams selected, all the steps in this checklist can be checked to verify if the landfill is in compliance with the acceptance criteria defined.		
Waste streams selected:		
Waste code and name: *1.120199 Blasting material* *2.200307 Fly ash (oil)* *3.170504 Soil from contaminated site* *4.190805 Sludge waste water treatment* **Description:** **1.** **2.** **3.** 4.		
Record of incoming information	**In compliance?**	
	YES	**NO**
Period for which records with required information are kept		
The operator shall keep records of information required for a period to be defined by the Member State. In your member state this . . (Regulation in which this is required is prescribed by national regulations)		

Are the basic characterisation documents kept according to the period determined in your national legislation ?		

Registration of data fundamental requirements for basic characterisation of the waste in records		
Do the records contain the following information ? (1.1.2. Council Decision of 19 December 2002)	**YES**	**NO**
(A) The source and origin of the waste **1.** **2.** **3.** **4.**	**1.** **2.** **3.** **4.**	**1.** **2.** **3.** **4.**
(B) Information on the process producing the waste (description and characteristics of raw/input materials and products) **1.** **2.** **3.** **4.**	**1.** **2.** **3.** **4.**	**1.** **2.** **3.** **4.**
(C) Description of the waste treatment applied in compliance with Article 6(a) of the Landfill Directive, or a statement of reasons why such treatment is not considered necessary *treatment: means 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* Is there a description of the treatment / No pre-treatment of waste necessary ? **1.** **2.** **3.** **4.**	**1.** **2.** **3.** **4.**	**1.** **2.** **3.** **4.**

Does the pre-treatment involve appropriate selection of different waste fractions and the stabilization of the organic fraction of waste? **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**
(D) Data on the composition of the waste and the leaching behaviour, where relevant: Is the number of protocol used for analysis mentioned in the basic characterization of waste made by the producer ? **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**
(E) (physical) Appearance of the waste (odour, colour, physical form) **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**
(F) Code according to the European waste list (EWC) 1.120199 Blasting material 2.200307 Fly ash (oil) 3.170504 Soil from contaminated site	**1. Yes** **2. Yes** **3. Yes** **4. Yes**	**1.** **2.** **3.** **4.**

4.190805 Sludge waste water treatment		
(G) For hazardous waste in case of mirror entries: the relevant hazard properties according to Annex III to Annex III to Directive 2008/98/EC: Please add information (H-codes) In case of non-hazardous waste, does the bulletin contains the analysis of leach ate and analysis of hazardous properties? 1. - 2. - 3.170504 Soil from contaminated site (MIRROR-CODE) **4. -**	**1. -** **2. -** **3.** **4. -**	**1. -** **2. -** **3. No** **4. -**
(H) Information to prove that the waste does not fall under the exclusions of Article 5(3) of the Landfill Directive Information about dry matter? Waste that falls within the scope of article 5 (3) is : (a) liquid waste (b) waste which in conditions of landfills is explosive, corrosive, oxidising, highly flammable or flammable (c) hospital and other clinical wastes arising from medical or veterinary establishments, which are infectious as defined (property H9 in Annex III) by directive 2008/98/EC and waste falling within category 14 (Annex I.A) of that directive (d)whole used tyres (2003) excluding tyres used as engineering material and shredded used tyres (2006) excluding in both instances bicycle 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. **1.** **2.** **3.** **4.**	**1.** **2.** **3.** **4.**	**1.** **2.** **3.** **4.**
(I) If necessary, additional precautions to be taken at the landfill **1.** **2.** **3.**	**1.** **2.** **3.**	**1.** **2.** **3.**

4.	**4.**	**4.**
(J) Check if the waste can be recycled or recovered: **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**
(K) Check on location one or several documents from this year to ensure that they comply with the demands. **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**

Testing Basic characterisation (1.1.3 Council Decision of 19 December 2002)		
Stable, non-reactive waste		
Check if they are allowed in the landfill and what the operator and inspection authority check (leaching test, chemical-physical treatment…) Stable non-reactive means that the leaching behaviour of the waste will not change adversely in the long-term, under landfill design conditions or foreseeable accidents: - in the waste alone (for example, by biodegradation), - under the impact of long-term ambient conditions (for example, water, air, temperature, mechanical constraints), - by the impact of other wastes (including waste products such as leach ate and gas). Did the Member States set criteria to ensure that hazardous monolithic wastes are stable and non-reactive before acceptance in landfills for non-hazardous waste? ..... Are any of the wastes stable, non-reactive? Information about TOC or loss of ignition? 1. 2. 3. 4.	**1.** **2.** **3.** **4.**	**1.** **2.** **3.** **4.**

Basic characterisation Waste must be tested to obtain the necessary information for basic characterisation (See D above). In addition to the leaching behaviour, the composition of the waste must be either know or determined by testing. The scope of (basic) characterisation, the extent of laboratory testing required and the relationship between characterisation and compliance testing depends on the type of waste. A differentiation can be made between:
A. Wastes regularly generated in the same process (individual and consistent wastes regularly generated in the same process, where: the installation and the process generating the waste are well known and the input materials to the process and the process itself are well defined the operator of the installation provides all necessary information and informs the operator of the landfill of changes to the process (especially changes to the input material). The process will often be from a single installation but the waste can also be from different installations, if it can be identified as a single stream with common characteristics within known limits/facilities (e.g. bottom ash from the incineration of municipal waste)
B. Wastes that are not regularly generated These wastes are not regularly generated in the same process in the same installation and are not part of a well-characterised waste stream. Each batch produced of such waste will need to be characterised. The basic characterisation shall include the fundamental requirements for basic characterisation. As each batch produced has to be characterised, no compliance testing is needed
C. Cases where testing is not required
(a) When the waste is on a list of wastes not requiring testing as laid down in section 2 of this Annex being: 10.11.03 (waste glass-based fibrous materials), 15.01.07 (glass packaging glass), 17.01.01 (concrete), 17.01.02 (bricks), 17.01.03 (tiles and ceramics), 17.01.07 (mixtures of concrete, bricks, tiles and ceramics), 17.02.02 (glass), 17.05.04 (soil and stones), 19.12.05 (glass), 20.01.02 (glass), 20.02.02 (soil and stones)
(b) All the necessary information, for the basic characterisation, is known and duly justified to the full satisfaction of the competent authority
(c) Certain waste types where testing is impractical or where appropriate testing procedures and acceptance criteria are unavailable. This must be justified and documented, including the reasons why the waste is deemed acceptable at this landfill class.

For the selected waste stream : do you agree with the way the waste stream has been categorised in (a) regularly generated (b) not regularly generated (c) or cases where testing is not required by the installation owner ? For the waste stream which you have selected for the inspection, has it been classified in the right class? **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**

Compliance testing - waste producer(1.2. Council Decision of 19 December 2002)		
When a specific waste is qualified for a certain landfill class on the basis of basic characterisation it shall subsequently be subject to compliance testing to determine if it complies with the results of the basic characterisation and the relevant acceptance criteria. The directive distinguishes between: 2.1 criteria for landfills for inert waste 2.2.criteria for landfills for non-hazardous waste 2.3 criteria for hazardous waste acceptable at landfills for non-hazardous waste pursuant article 6(c)iii 2.4.criteria for waste acceptable at landfills for hazardous waste 2.5 criteria for underground storage) The Member States shall determine which of the test methods and corresponding limit values in the table should be used. Your national legislation in which this is implemented is:		
	IN COMPLIANCE	
	YES	**NO**
For the selected waste streams has compliance testing been performed? selected waste stream : **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**

Are all the tests of the compliance testing in agreement with the ones used in the basic characterisation procedure? **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**
Is a batch leaching test done in agreement with the sampling and testing methods (section 3 of the Council Decision of 19 December 2002) ? **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**
Do the results of the analyse test show that the waste meets the limit values for critical parameters and may the waste be accepted at this landfill? **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**	 **1.** **2.** **3.** **4.**
Is the frequency of compliance testing in agreement with the frequency of the basic characterisation? **1.** **2.** **3.** **4.** If not, how often is the compliance test performed? **1.** **2.**	 **1.** **2.** **3.** **4.** **1.** **2.**	 **1.** **2.** **3.** **4.** **1.** **2.**

3. **4.**	**3.** **4.**	**3.** **4.**
Records (data) of the analytical results shall be kept for a period that will be determined by the Member States legislation; are the records kept for the time required ? 5 Years.....	Yes	

On-site verification (1.3. Council Decision of 19 December 2002)		
Each load (batch) of waste delivered to a landfill shall be visually inspected before and after unloading. The documentation required shall be checked. During the visual inspection on the landfill focus on the way the waste is visually checked and who is responsible for this. Is there physical space to perform an inspection of a waste delivery?		
The waste may be accepted at the landfill, if it has the same composition as is the waste that has been subjected to the basic characterisation procedure and the compliance testing and the descriptions in the accompanying documents. If this is not the case, the waste may not be accepted.		
Are records (data) kept of waste that has not been accepted at the landfill ? .		
Member States shall determine the testing requirements for on-site verification, including rapid test methods where appropriate. Legislation in member state? ..... Is this part of the acceptance procedures in compliance with this legislation		
Upon delivery, samples (the operators compliance testing) shall be taken periodically. The samples taken shall be kept after acceptance of the waste for a period that will be determined by the Member State (see Article 11(b) of the Landfill Directive not less than one month) Period that sample shall be kept according to legislation is :		

SAMPLING OF WASTE

Sampling and test methods (according to Council Decision of 19 December 2002; 2003/33/EC)	**In compliance?**	
	YES	**NO**
Check if testing complies with sampling and test methods indicated in Council Decision of 19/12/2002 (see Annex chapter 3) *Sampling and testing for basic characterisation and compliance testing shall be carried out by independent and qualified persons and institutions. Laboratories shall have proven experience in waste testing and analysis and have an efficient quality assurance system.* *Member States may decide that:* - *the sampling may be carried out by producers of waste or landfill operators under the condition that sufficient supervision of independent and qualified persons or institutions ensures that the objectives as set out in this Decision are achieved;* - *the testing of the waste may be carried out by producers of waste or operators if they have set up an appropriate quality assurance system including periodic independent checking.* **For sampling** Sampling performed by an independent certified /accredited person /institution according to national / EN technical standards. **For analyses** Certified / accredited laboratory perform analyses according to national / EN technical standards ,		

SAMPLING CHECK (preparation (desk study) & on-site visit)	**What kind of information is to be checked ?**	**Compliant Yes / No ?**
Ask for **complete Landfill Documentation** (since last assessment)	**data available ?**	

Select waste type for check (see the above selected types of waste)	**Waste stream ? single batch waste ?**	
Ask for sampling plan of selected waste	Check if the data is complete	Compliant Yes / No ?
Does a sampling plan & additional information (photos, tables) exist ?		Y/N ?
In-depth check of sampling plan:		Compliant yes/no ?
Project name, waste owner, contact person, document identification		Y/N
Was the sampling plan prepared by an authorised person /institution ? (Check certificate /accreditation against national legislation)		Y/N
Accreditation certificate issued by authority (name) ?		Y/N
Purpose of sampling ?		
	for basic characterisation of waste ?	Y/N
	for landfill purpose ? *(is the purpose of sampling that the waste is finally going to a landfill)*	Y/N
	for recovery of waste ?	Y/N
Is a waste code assigned (according to EWC or national standards)	waste code number	Y/N
Does the waste code represent the quality of the waste ?		Y/N
Origin of waste ? (Production process, waste collection, treatment)	Information sufficient /reliable ?	Y/N
Relevant input materials (especially when waste was processed/treated)	Information sufficient /reliable ?	Y/N
Description of waste quality	Material not contaminated ?	Y/N
	Material obviously contaminated ?	Y/N

	Contamination very likely / to be expected ?	Y/N
Background information on the waste in question	Previous investigations /analysis available ?	Y/N
Document signed /approved by waste owner (other) ?		Y/N
Statistical approach according to legislation		
Waste mass (kg, tons, m^3)		Y/N
Density ?		Y/N
Size of population sampled	According to national /EU standards ?	Y/N ?
Number of samples taken	According to national / EU legislation & technical standards ?	Y/N ?
Mass (size) of samples taken	Is the (minimum) amount defined by legislation	Y/N ?
	or computed according to technical standards	Y/N ?
Sampling plan	Content **according to Annex A table A.1 of EN 14889** or national legislation (if more comprehensive)	Y/N
Sampling protocol	Content according to **Annex A table B.1 of EN 14889** or national legislation (if more comprehensive)	Y/N
Is the sampling plan compliant to national /EU legislation (e.g. according to EN 14899 standard) ?		Y/N
On-site assessment		

On-site demonstration of sampling	Who is in charge of this ? landfill operator ? waste owner / waste producer ? certified lab on behalf of the operator ? certified lab on behalf of waste producer?	 Y/N Y/N Y/N
Check sampling equipment used	Is the equipment /machinery according to the sampling method required ?	Y/N
Who is in charge of equipment ? landfill owner /other ?	Landfill operator?	Y/N
	external qualified expert ?	Y/N
	other ?	Y/N
On-site demonstration of sampling	performed according to sampling plan and technical standards ?	Y/N
Replicate samples	replicate samples taken ?	Y/N
Storage of replicate samples	On-site storage facility available ?	Y/N
	or storage at a certified lab ?	Y/N

ANNEX 4: LANDFILL OPERATOR SELF-MONITORING PLAN: MINIMUM CONTENT

GENERAL CONDITIONS FOR THE EXECUTION OF THE PLAN

Obligation to execute the plan

Access to sampling points: the operator shall provide secure access to all sampling points, in compliance with the relevant technical standards and in particular to

- sampling points for atmospheric emissions;
- sampling wells for wastewater;
- groundwater monitoring piezometers;
- waste storage areas at the site;
- noise emission measurement points.

For each sampling activity, a copy of the sampling plan with the relevant test reports attached must be kept at the installation and made available to the competent authority within the annual self-monitoring report.

Evaluation of the outcomes of self-monitoring

The operator, if not already provided for in the EMS, must provide a procedure for evaluating the results of self-monitoring. This procedure must provide for the analysis of the non-compliances and the measures implemented to restore normal conditions and prevent the non-compliances from recurring, as well as an evaluation of the effectiveness of the measures taken.

Data management and presentation

1. The operator must ensure that all results of monitoring and control activities are stored on a suitable digital medium for a period of at least ten years, including information on data generation.
2. The data proving the execution of the monitoring must be made available to the Competent Authority at every request and, in particular, at the time of periodic inspections.

ENVIRONMENTAL COMPONENTS

Monitoring Obligations of the operator

It is specified that, with regard to the column ***Method of recording of monitoring carried out, it*** is preferable to record the data on an editable computer medium. In this column, it is advisable to indicate the recording method adopted and the reference of the register (paper or preferably digital) that may be requested during the inspection visit by the control authority (e.g. indicate the title of the register or the EMS procedure in which it is inserted).

Raw materials and waste input

The operator must report the annual consumption of raw and auxiliary materials (taking into account any stocks in the warehouse), as well as the presence of Substances of Very High Concern (SVHC), when preparing the annual Report.

Table 1 - Raw and auxiliary materials (substances/mixtures)

Name Code (CAS, ...)	Hazard Classification (CLP)	Phase of use	Physical state	Storage modes	Storage area	Measurement method	Annual consumption	Method for recording of monitoring carried out
Indication of raw materials consumed in the various processes		*Description of the process step in which the material is used*	*Description physical composition of the material (solid/liquid)*	*Indication of storage methods (drums, big-bags, etc.)*	*Indication of storage area*	*Provide information on measurement methods*	*Indication of the aggregate figure in tonnes/year of the year's consumption*	*Indication of data collection mode: paper or digital format; indication of relevant EMS register*

Table 2 - Waste entering the landfill: details

EER	Region of origin	Quantity	Hazard characteristics	Regularly/not regularly produced waste	Basic characterisation (n. lab bulletin)	Verification of conformity (n. lab bulletin)	Frequency	Method for recording of monitoring carried out
EER XXXX								

For each waste, a list of the basic characterisations relating to it must be attached.

Table 2a - Waste entering the landfill: flow analysis

EER	NHW input quantities	Stable non-reactive (SNR) HW input quantities	Quantities of waste containing asbestos	Quantities of NHW delivered from outside the region	Quantities of SNR delivered from outside the region
EER XXXX					
EER XXXX					
TOTAL					

Enclose a plan of the cells for asbestos and stable non-reactive hazardous waste with this table

Table 2b - Waste acceptability criteria

Activities	Control modes	Measurement point and frequency	Mode of registration
Quantity check	Weighing	With each load	
Documentary verification	EER verification, physical state, provenance, presence of basic characterisation	With each load	
Visual inspection	Verification of cargo conformity with the form	With each load	
Analytical verification of conformity	Verification (visual and/or homologous evaluation and/or mixing tests) of compliance of index contaminants with the Basic Characterisation	For regularly generated waste, same frequency as for Basic Characterisation	

The results of conformity audits are retained for five years.

Radiometric control of incoming raw materials/waste

In the event that the waste entering the installation is subject to radiometric control by means of a portable detector, a summary of the anomalies, drawn up according to the format of the following table, must be included each year in the self-monitoring report:

Table 2c - Radiometric checks (anomalies)

Waste name/description/EER	Storage mode and quantity	Used Instrumentation	Control date	Anomaly recorded	Method for recording of monitoring carried out
Indication of the EER code of the waste and its designation	*Description of how the quarantined waste is handled and the quantity of the load*	*Indication of the instrumentation used and the relevant methods employed (including calibration)*	*Indicate the date on which the anomaly was detected*	*Indication of the recorded value, date and details of communication to the authority*	*Indication of data collection mode: paper or digital format; indication of relevant* EMS *register*

Table 3 - Water resources 'supply'

Source	Pick-up point	Phase of use and measuring point	Type of use (sanitation, wetting, vehicle washing, etc.).	Measurement method and frequency	Consumption	Method for recording of monitoring carried out
Indicate the type of water resource (well, network, etc.)	*Indication of where the resource is withdrawn (water mains delivery point, well, tank, tanker truck, etc.).*	*Indication of the process step in which the resource is used*		*Providing information on measurement methods e.g. invoices, direct measurements*	m^3	*Indication of data collection mode: paper or digital format; indication of relevant EMS register*

The following table is intended to show the amount and percentage of water recovered (e.g. purified water recovery, rainwater)

Table 3a - 'Recovery' water resources

Source Recovered water	Percentage of water recovered	Pick-up point	Phase of use and measuring point	Utilisation (sanitation, wetting, vehicle washing, etc.)	Measurement method and frequency	Consumption	Units of measurement	Method for recording of monitoring carried out
purified water, stormwater						m^3		

Table 4 - Fuels

Type	Phase of use and measuring point	Storage capacity	Measurement method and frequency	Consumption	Quality	Units of Measurement	Method for recording of monitoring carried out
Indicate the type of fuel diesel/oil/biofuels	*Description of the process in which it is used (machine/vehicle, etc.) and how fuel consumption is quantified*		*Provide information on measurement methods e.g. invoices, direct measurements. Temporal frequency of measurement (quarterly/semi-annually/annually)*		*Indicate fuel characteristics such as sulphur, lead and benzene content*		*Indication of data collection mode: paper or digital format; indication of relevant EMS register*

Table 5 - Energy Resources

Energy consumed	Utilities	Department of use	Consumption	Units of Measurement	Method of measurement	Frequency of control and data recording	Recording modes
Electric	*Indicate and describe the type of user (industrial/civil)*	*Total for industrial use*		MWh	Direct meter reading or estimation	Monthly	
Thermal	*Indicate and describe the type of user (industrial/civil)*	*Total for industrial uses*		MWh			
Energy produced							
Type	**Utilities**	**Department of use**	**Production**	**Units of Measurement**	**Method of measurement**	**Frequency of control and data recording**	**Recording modes**

Energy consumed	Utilities	Department of use	Consumption	Units of Measurement	Method of measurement	Frequency of control and data recording	Recording modes
Electric	*Indicate and describe the type of user (industrial/civil)*	*Total for industrial use*		MWh	Direct meter reading or estimation	Monthly	
Thermal	*Indicate and describe the type of user (industrial/civil)*	*Total for industrial uses*		MWh			

Emissions to atmosphere

Table 6a - Piped atmospheric emissions (biogas)

Pollutants and parameters monitored discontinuously

Emission point abbreviation	Parameter	u.m.	Frequency	Method	Method for recording of monitoring carried out
	CH_4 , CO_2 , O_2 , H_2 , H_2S, Total dust, NH_3 , Mercaptans, Flow rate, temperature		*Monthly (half-yearly in post-management)*		

The information may be returned in accordance with the "*Sample outline of the discontinuous checks format referred to in points 2.5 and 2.7*" of Annex VI to Part V of Legislative Decree 152/06 (example attached to *Guideline 74/CF check-list AUA-AIA_GdL 11:2016*.

Table 6b - Quantity of biogas produced

Emission point abbreviation	Quantity of biogas extracted and flared	Quantity of biogas extracted and used for energy production	Recording modes

Table 7 - Air quality

Pick-up point	Parameters	Method of measurement	Frequency	Recording modes
	Potential gas emissions		*Monthly (half-yearly in post-management)*	
	Free asbestos fibres (for landfills where asbestos is disposed of)	*MOCF*	*Monthly (half-yearly in post-management)*	

As a rule, at least two measuring points should be provided along the main wind direction: one upstream, the other downstream of the landfill. Please attach the plan with the measurement points and the meteoclimatic station reading for determining the wind direction on the sampling days.

Table 7a - Diffuse Emissions from the landfill body

Measuring point from the landfill body/outside the landfill	Measure	Control modes	Control frequency	Sampling and analysis method	Recording modes

For landfills where biodegradable waste is disposed of, gas emission monitoring must be provided to detect gas leaks from the landfill body. Warning levels must also be identified for the presence of landfill gas outside the landfill, including in the soil and subsoil.

Attach the plan with the identified measurement points. The Self monitoring Plan must contain the control methods and relevant warning levels concerning diffuse biogas emissions outside the landfill, into the soil and subsoil.

Table 7b - Odour Emissions

In cases where issues related to nuisance odour emissions are detected, the following control methods should be included.

The operator must implement a programme to monitor the maintenance of all the technical-operational procedures necessary to limit odorous emissions, through verification of the facilities in operation, by recording visual and instrumental inspections and maintenance at potential sources (e.g. leachate storage, etc.).

The operator must also submit a summary table, such as the one below, indicating the identified sources of odorous substances and the countermeasures implemented for odour containment (odorous waste storage areas, storage holdings, waste treatment coverage, substance substitution, conveying, abatement).

Description	Self-checking frequency	Source points	Recording modes
Predictive impact assessment	Once		
Chemical characterisation of odour sources	Once		
Environmental analysis by dynamic olfactometry (UNI EN 13725) at emission sources and at the plant boundary	Biennial in operation		

Table 7c - *Meteoroclimatic data*

Description	Frequency self-check Operation phase	Frequency self-check post Operation phase	Recording modes
Precipitation	Daily	Daily added to monthly values	
Temperature min, max 14 h CET	Daily	Monthly average	
Evaporation	Daily	Daily added to monthly values	

Description	Frequency self-check Operation phase	Frequency self-check post Operation phase	Recording modes
Wind direction and speed	Daily	Not required	
Atmospheric humidity (14 h CET)	Daily	Monthly average	

Emissions to water

Table 8 - Discharges from the landfill

Emission point	Type of discharge Direct/indirect*	Address	ETRS coordinates 1989	Measures to be carried out**	Frequency	Presence of authomatic sampler (YES/NO)	Recording and transmission modes
		Sewerage, water body (name), soil		Flow rate, pH, Temperature			

*"Direct discharge": into water body/soil; "Indirect discharge": into sewers

**For emissions to water, monitoring of key process parameters (including continuous monitoring of wastewater flow rate, pH and temperature) at key points (e.g. where possible/necessary, at pre-treatment and final treatment inlet points) should be considered BAT.

Table 8a - Emissions to water - monitored pollutants

Emission code	Origin phase	Parameter	Sampling and measurement method	Frequency	Recording modes
				In the case of indirect discharge into a receiving water body, the frequency of monitoring may be reduced if the downstream waste water treatment plant removes the pollutant.	

Table 8b- Leachate treatment

Treatment system	Checkpoints for proper functioning	Control modes	Control frequency	Arrangements for recording checks carried out
Define section Purification plant	Control well upstream and downstream	Checking abatement efficiency by analytical control of monitored pollutants		Annotation of any anomalies in the plant operating register Archiving of analytical certificates
	Define process parameter control for correct functioning			

Table 8c - Runoff water

Sampling point	ETRS coordinates 1989	Composition	Frequency	Address	Recording modes
Sampling point identification code as per approved plan			*Composition: Quarterly (operation.), Half-yearly (post-operation.)*	*Indicate the final destination (water body, soil, etc.).*	

These measurements must be carried out on runoff water affecting the temporary or permanent cover.

Noise

The operator must carry out an update of the acoustic impact assessment with respect to the outdoors with the required frequency, in order to verify compliance with the limits set by the municipal acoustic classification and in any case with the regulatory limits.

The noise impact report must include Leq measurements for the entire day and night period, hourly Leq values, a description of how the sources were operated during the measurement campaign and georeferencing of the measurement points.

Measures to verify compliance with the prescribed limits and values must be carried out excluding contributions from noise sources other than the establishment.

Table 9- Noise

Measuring station	Descriptor	Control modes	Frequency of measurement	Registration mode

Measuring station	Descriptor	Control modes	Frequency of measurement	Registration mode
Measurement point identification (descriptive, co-ordinates, ref. plan attached)	L_{Aeq}	*Checking limits* *Or* *Test-point: Sampling for verification of maintenance of compliance with limits*	*For new installations verification after the first year of operation* *and subsequently* *triennial and/or following major plant modifications or after noise mitigation measures*	*Archiving of noise measurement results and noise survey report - Inclusion of noise impact report in the Annual Self-monitoring Report*

Waste generated

1. The Operator shall carry out the appropriate analyses on the waste produced in accordance with the law and shall provide for the drafting of sampling plans with reference to standard UNI EN 10802:2013 and/or other specific technical standards.
2. The analytical certificates for the characterisation of the waste produced, signed by the person in charge of the laboratory in charge, must state the method(s) used and must be available to the control authority.
3. The operator must file and keep all analytical certificates for the characterisation of the waste produced, signed by the appointed laboratory manager and specifying the methods used, in order to make them available to the Control Authority.
4. The Manager must fill in the following tables on a monthly basis:

Table 10 - Leachate produced

Point of sampling	Product quantity	Output quantity	Total quantity in stock	Final disposal/recovery plant[33]	Ref. bulletins analysis of compliance with technical and environmental requirements	Composition	Registration mode

[33] Indicate both the transaction code D or R and the name of the destination facility.

Point of sampling	Product quantity	Output quantity	Total quantity in stock	Final disposal/recovery plant[33]	Ref. bulletins analysis of compliance with technical and environmental requirements	Composition	Registration mode
	Monthly frequency (half-yearly in post-management)					*Quarterly frequency (half-yearly in post-management)*	*Indicate the registration method adopted and the register reference*

Indicate the correlation of leachate production with weather and climate data.

Table 10a - Other waste generated

Name (EER)	Quantities produced	Output quantities	Total quantity in stock	Final disposal/recovery plant[34]	Ref. bulletins analysis of compliance with technical and environmental requirements	Registration mode
					For each batch of waste produced	

[34] Indicate both the transaction code D or R and the name of the destination facility.

Table 10b - Classification and acceptability of waste generated

Monitoring of the state of the waste storage must be carried out according to the following table:

Table 10c - Waste storage: temporary storage or stockpiling

Storage	**Storage status control mode**	**Frequency of control and data recording**	**Mode of registration**
Outdoor storage areas (for solid waste)	Visual inspection	Quarterly	Quarterly recording on internal management register
Liquid waste storage areas in sealed containers with containment basin	Visual check of the tightness of the waste containers and the containment basin	Quarterly	Quarterly recording on internal management register

Table 10d - Leakage minimisation

Well	**ETRS coordinates 1989**	**Depth**	**Date of measurement**	**Leachate level detection**	**Method of measurement**	**Control frequency**	**Mode of registration**
Measurement point identification (descriptive, ref.plan attached)						Monthly	

3.1.6 - Groundwater Monitoring

Table 11 - Groundwater Monitoring

Piezometer	Parameters	Method of measurement	Sampling method used	Frequency measurement	Recording modes
N.....				Water table level: monthly (half-yearly in post management) Composition: quarterly (half-yearly in post-management)	Filing of analytical certificates and drafting of a report on the state of soil and subsoil contamination, based on the results of monitoring, in which the measures to secure any contamination situations detected must be indicated. The measured values should be related to trigger levels.
N.....					
N.....					

3.1.7 - Landfill Topography

Table 12 - Topographical surveys

Survey date	Volumetry occupied by waste	Volumetry occupied by topsoil	Residual volume	Settlement	Frequency	Recording modes
.....	.....	.....			*Operational management: Landfill body settlement: six-monthly; Morphology/structure and composition: annual.*	

Survey date	Volumetry occupied by waste	Volumetry occupied by topsoil	Residual volume	Settlement	Frequency	Recording modes
					Post-operational management: Landfill body settlement at least every six months for the first three years, then annually	
.....	.....	.....				
.....	.....	.....				

Report the structure and composition of the landfill annually.

Report half-yearly on landfill settlement behaviour.

INSTALLATION MANAGEMENT

Common provisions - management prescriptions:

a) Environmental Management System (EMS)

The results and actions taken within the framework of the audits foreseen in the EMS must be reported in the periodic self-audit report.

Table 13 - EMS Audit (REPORTING)

Audit (internal/external)	Date	Non-conformity/criticality	Actions taken

Control of critical phases

In order to guarantee the control of the critical phases of the process, the Manager shall keep an up-to-date list of measuring instruments as well as of environmentally critical equipment and parts of the plant, for which he shall define a maintenance plan on an annual basis, containing a description of each intervention, its frequency and recording methods. The identification of these instruments/equipment shall take into account the following minimum criteria:

- characteristics of the contained substance (e.g. toxic, corrosive, flammable) and composition material of the equipment,
- likelihood of spillage of the substance,
- operating conditions (T° and p)

In any case, the list must include all the instrumentation necessary to control the environmentally critical phases (pHmeters, flow meters, thermometers, continuous analysers, etc.).

Communications to the competent authorities

a) The Operator shall promptly notify the competent Authority of the non-admission of waste to the landfill.
b) The Manager registers and communicates in the shortest possible time to the competent Authority, the events considered critical from an environmental point of view.
c) If not already provided for in the Environmental Management System or by dedicated software, the operator must draw up a maintenance manual that includes the maintenance procedures adopted from the technical manuals; maintenance records must be made available for verification.

d) The operator must record in a dedicated register, to be kept available for inspection by the competent authority, all anomalies, failures and malfunctions occurring at the plant.
e) All the above information should be summarised in a table and submitted as an appendix to the Annual Report.

b) Incidental Event Management

Table 15 - Accidental events

Type of Event	Processing stage	Prevention modes	Control mode	Start (date,time)	End (date,time)	Communication to the Authority (Protocol No. of)

Reporting accidents or unforeseen events that significantly affect the environment

In the event of accidents or unforeseen events that significantly affect the environment, the Manager must immediately inform the Competent Authority and must immediately adopt measures to limit the environmental consequences and prevent any further accidents or unforeseen events.

The above-mentioned communication must contain:

a) the description of the accident or unforeseen events,
b) the substances released (also with reference to the hazard class of the substances/mixtures according to Regulation 1907/06),
c) duration,
d) environmental matrices involved
e) measures to be taken immediately to limit environmental consequences and prevent further accidents or unforeseen events.

c) Performance Indicators

In this section, the operator must identify process-specific indicators that allow for immediate verification of the installation's performance.

In the annual report that the operator will forward to the Competent Authority the trend for each indicator must be reported, for the available time span (a minimum of three/five years), with the evaluations of merit with respect to the possible values defined by the sectoral Guidelines available both nationally and at EU level.

Table 16 - Performance Indicators

Indicator*	Units of Measurement	Relief frequency	Value
Specific consumption of water, energy, fuels			
Specific leachate production			
Specific biogas production			
Specific energy recovery			
.....			

d) Annual Report

The Manager is responsible for validating, evaluating, archiving and storing all registration documents relating to monitoring activities in the Company's archives, including copies of certificates of analysis and the results of checks carried out by external suppliers.

All data collected during the execution of the monitoring plan must be stored by the company on a suitable digital medium for at least 5 years and made available for any checks by the relevant bodies.

Annually, **by 30 April** of the year following the year of reference, the operator must transmit to the competent authority the results of the monitoring plan relating to the previous calendar year and a report highlighting the conformity of the operation of the installation with the conditions prescribed by the permit. The conformity assessment also includes a statistical comparison between the measurements, their uncertainties and the reference limit values or equivalent requirements.

The values of measurements and monitoring data depend on the degree of reliability of the results and their comparability.

The annual report should therefore include a summary and effective presentation of the monitoring results and all data and information related to regulatory compliance, as well as considerations of environmental performance improvement targets. Corrective actions implemented as well as environmental improvement actions taken should be indicated.