This publication was withdrawn on 21 April 2021

It has been replaced by Landfill operators: environmental permits.

How to comply with your environmental permit
Additional guidance for:

Landfill (EPR 5.02)

We are the Environment Agency. It's our job to look after your environment and make it a better place – for you, and for future generations.

Your environment is the air you breathe, the water you drink and the ground you walk on. Working with business, Government and society as a whole, we are making your environment cleaner and healthier.

The Environment Agency. Out there, making your environment a better place.

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Introduction

In *"Getting the basics right – how to comply with your environmental permit"* (GTBR) we described the standards and measures that we expect businesses to take in order to control the risk of pollution from the most frequent situations in the waste management and process industries.

This sector guidance note (SGN) is one of a series of additional guidance for Part A(1) activities listed in Schedule 1 of the Environmental Permitting Regulations (the Regulations). We expect you to use the standards and measures in this note **in addition** to those in GTBR to meet the objectives in your permit.

Sometimes, particularly difficult issues arise such as problems with odour or noise. You may then need to consult the "horizontal" guidance that gives in depth information on particular topics. Annex 1 of GTBR lists these.

The European Commission has not produced a best available techniques reference document (BREF) for landfill. Instead the Landfill Directive provides certain technical standards for landfill sites. Where the Landfill Directive does not provide the relevant technical requirements then the general principles of the IPPC Directive must be applied.

When making your application, explain how you will comply with each of the recommendations in this sector guidance note.

We will consider the relevance and relative importance of the information to the installation concerned when making technical judgements about your installation and when setting conditions in the permit.

Modern permits describe the objectives (or outcomes) we want you to achieve. They don't normally tell you how to achieve them. They give you a degree of flexibility. Where a condition requires you to take appropriate measures to secure a particular objective, we will expect you to use, at least, the measures described which are appropriate for meeting the objective. You may have described the measures you propose in your application or in a relevant management plan but further measures will be necessary if the objectives are not met.

The measures set out in this note may not all be appropriate for your particular circumstance and you may implement equivalent measures that achieve the same objective. In cases where the measures are mandatory, this is stated.

In response to the application form question regarding operating techniques, you should address, in particular, the main measures you will use to control the issues in this document as well as the key issues identified in GTBR.

Unless otherwise specified, the measures and benchmarks described in this note reflect those of the previous Sector Guidance Note.

Introduction

There are a number of key environmental issues for landfill sites. When we look at your application we have to consider whether your proposed operations will meet the necessary standards. The key issues are set out in this section. We will need to agree that your proposals for issues such as engineering the site and managing the landfill gas from the site are appropriate before we grant you a permit. There are further, more detailed technical guidance documents for landfills. This document describes the main technical requirements for landfills but reference is sometimes made to more detailed landfill guidance.

Installations Covered

This note applies to landfills that are IPPC Part A installations landfills regulated under the following section of schedule 1 of the Regulations:

Section 5.2, Disposal of waste by landfill, Part A(1),

(a) The disposal of waste in a landfill—

(i) receiving more than 10 tonnes of waste in any day, or

(ii) with a total capacity of more than 25,000 tonnes,

but excluding disposals in a landfill taking only inert waste.

This guidance is also relevant to landfills (other than inert) that are closed or closing under previous legislation. For those landfills, this guidance can assist in understanding the technical measures we regard as best practice and as such may be applicable. However, we will only apply these if relevant to your current permit conditions, and through discussion if we need to modify your permit conditions.

Guidance on EPR Landfill Installations

This is Edition 1 of the EPR Landfill Installation Guidance.

It has been updated to reflect legislative changes, but has not undergone a full technical review. It is recognised that this Sector Note needs a full technical review and consultation. We hope that will be completed within the next six months.

This amends and replaces previous versions of the Landfill Sector Guidance Note 5.02. The changes can be summarised as follows:

1. To refer to the current legislative framework i.e. Environmental Permitting Regulations and Landfill Directive, as the previous version referred to the Landfill Regulations.
2. It reflects improvements to our guidance structure. We have removed duplicate references to information that is within GTBR.
3. It refers directly to Defra and WAG Environmental Permitting Guidance on the Landfill Directive, and to our regulatory guidance on Understanding the Landfill Directive, LFD1.

Introduction

4. The scope of the document has changed to refer to non-hazardous and hazardous landfills. We are producing separate guidance on the standards and measures for the deposit of inert waste on land. This is to take into consideration the Government review of inert regulation.
5. Technical changes have been limited to the removal of references to advice to operators on traffic management and sustainable development.
6. Other changes include improvement to the formatting for easier reading.

We are currently reviewing a number of our other landfill technical guidance documents to bring them in line with Environmental Permitting.

Once these have been revised, we will incorporate these changes into the SGN and this will form the basis of Edition 2 of SGN5.02. We will be seeking comments on Edition 2 of the SGN prior to its issue. Future changes may include:

- technical update on landfill gas management. We are reviewing our technical guidance with representatives from industry through the Landfill Gas Guidance Implementation Group
- management of odours
- landfill engineering standards
- guidance on landfill closure, management in post-operation phase and surrender
- waste acceptance procedures
- implementation of Groundwater Daughter Directive.

It is anticipated that we will be consulting on Edition 2 in summer 2009.

Key Issues

There are some key issues for the landfill sector you will need to manage effectively to ensure continuing compliance with your permit and to reduce risk to the environment. Our compliance assessment effort is likely to focus on these areas.

Waste acceptance

Understanding and controlling waste types is essential in managing the risk from your landfill. You have to give us, as part of the application form, a list of the waste types you wish to dispose at your landfill. We will include a list of permitted wastes as part of your permit.

Protecting groundwater

All landfills must meet the requirement of the Groundwater Regulations - to prevent the direct discharge of List I substances into groundwater and to prevent the pollution of groundwater by substances in List II. The IPPC Directive also requires that installations are operated in such a way that no significant pollution is caused, which for groundwater may incorporate substances beyond those in Lists I and II of the Groundwater Regulations. The Landfill Directive reinforces our duty to protect groundwater. Government guidance on the Landfill Directive (reference 3) explains the requirements,

Introduction

including on landfill location. Our guidance EPR LFD1, (reference 5) expands on the Government guidance, you should refer to both documents.

Managing landfill gas

Correctly managing landfill gas is a key element in operating a landfill.

All landfills receiving biodegradable wastes must have the following three elements:

- barriers to surface emissions and sub-surface migration of landfill gas
- an active gas extraction system to achieve the maximum practicable collection efficiency
- a system of gas treatment meeting emission standards.

Although biodegradable waste is not acceptable at landfills for hazardous waste, gas management for these landfills must also meet these three criteria.

You should refer to our detailed technical guidance on managing landfill gas (references 33 to 40).

Accident management

Considering potential environmental accidents is a key issue. For the landfill sector, landfill fires are a key concern. The stability of a landfill is also important because waste is generally a heterogeneous material subject to decomposition and consolidation over time.

Odour

Odour is a key issue, particularly for biodegradable waste landfills. Odour is typically associated with:

- trace components in landfill gas
- handling of odorous wastes
- covering of biodegradable wastes.

As a fugitive emission, preventative measures relating to the above are key.

Aftercare

Once waste deposit has finally ceased, it is essential you ensure ongoing aftercare. Particular elements to consider are:

- managing landfill gas and leachate
- monitoring
- maintaining infrastructure.

1

Managing your activities

Security

1. Managing your activities

1.1 Security

You must implement security measures to prohibit unauthorised access to the operational areas of your site. Operational areas include: areas of the installation where active tipping is taking place; leachate and gas plant and any area where landfill gas or leachate extraction systems are exposed and could be subject to deliberate damage. You may allow access to areas that are fully restored and where members of the public will not be adversely affected by the permitted activities carried out at your installation.

Security recommendations	
1	You should provide perimeter fencing and gates to prevent unauthorised access as far as practicable (including preventing free access to animals and wildlife, as required by the Animal By-products Regulations).
2	Security fencing may be appropriate for vulnerable locations. The suggested minimum height for security fencing is 2m with cranked top and barbed wire strands.
3	You should ensure perimeter fencing is inspected regularly by a nominated person.
4	You should maintain perimeter fencing in good repair at all times.
5	You should consider using the following measures to prevent free access to the site: • security cameras • security guard • intruder alarms, lighting, shutters and bars on accommodation.

Finance

1.2 Finance

Condition 1.3.1 of our permit template identifies the financial provision agreement made by the operator and requires it to be maintained. The condition refers to a specific agreement by using a date. This is to ensure that an application to vary the permit is made to fund any review of the performance agreement.

Condition 1.3.2 requires the waste disposal charges cover the costs of setting up, operating, closure and aftercare of the landfill, as required by the Landfill Directive, Article 10.

Financial provision

Financial provision for landfills must be 'adequate'. It must be sufficient, secure and available so you can discharge your permit obligations. The requirements are set out in the Policy on financial provision for landfills and associated guidance (reference 41).

Costs

Article 10 of the Landfill Directive relates to charges, rather than directly to the aftercare period, which is covered by Article 8. Article 10 requires you make provision for, 'at least' 30 years. For a site that has taken biodegradable waste, the period until permit surrender may be significantly longer.

You must be aware of the cost of each element of the works and of the landform as a whole. This should include the costs of site assessment, operations, environmental control and monitoring, restoration and aftercare, as well as of the preparation and development works. You should assess costs in terms of the total costs, the costs expressed per tonne of waste and costs against time over the whole life of your landfill.
If you fail to determine the financial viability of a project, it may lead to environmental problems if funds run short before its closure, restoration and completion.

Finance
Multiple operator installations

Cost recommendations	
1	You should define a consistent basis for cost assessment to allow a valid comparison of alternative designs or design elements.
2	You can extend your assessment of unit costs (£/m^3 or £/t) from a simple total to a calculation for each item. This will enable you to rapidly assess the effects of significant variable items. You should consider the distribution of development, restoration and aftercare costs across a landfill. In this way you can assess the cost for areas such as those at the perimeter where the waste is particularly thin, or those areas requiring difficult engineering works and you can adjust the sites boundaries and profile accordingly.
3	Managing leachate and gas from landfills for hazardous waste may require techniques which have been uncommon in the UK, and which may require off-site disposal of residues. You should fully reflect the costs for this, over the necessary timescale, in the charges you make (as well as in your financial provision).

1.3 Multiple operator installations

It is possible for the activities comprising a single installation to be operated by more than one operator. Each operator will be issued with a separate permit.

The condition within the permit (Condition 1.5) is intended to ensure that where there is more than one operator, they communicate with each other when the notification condition (4.3.1) is invoked.

Where there is more than one operator, the proposed techniques and measures (including those to be taken jointly by more than one operator) must ensure the satisfactory operation of the whole installation.

It is possible that actions that benefit the environmental performance of the overall installation will increase the emissions from one permit holder's activities. One example is where there is a separate operator for the landfill gas utilisation plant. If the landfill gas is extracted solely to provide fuel for the engines this may benefit the emissions from the engines but may impact on landfill gas migration control. Separate landfill gas extraction systems may be required for migration control and for gas utilisation in such cases.

Multiple operator installations Accident management plan

Recommendations for multi-operator installations
1 You should consider possibilities for minimising impact to the environment as a whole, by operating together with other permit holders. Possibilities include: • communication procedures between the various permit holders; in particular those needed to ensure the risk of environmental incidents is minimised • ensuring the effective extraction of landfill gas • combining leachate to justify a combined or upgraded effluent treatment plant; • combining gas flaring/energy generation plant • avoiding accidents (see Condition 1.1) from one activity which may have a detrimental knock-on effect on the neighbouring activity • land contamination from one activity affecting another.

1.4 Accident management plan

Recommendations for accident management plan
1. Particular areas of accidents you should consider at landfills may include, but should not be limited to, the following: • uncontrolled migration of landfill gas • explosion • waste slippage • failure of a basal or side wall liner • incompatible wastes coming into contact • release of leachate to an uncontained area • overfilling of tanks/lagoons • emission of a treated leachate before adequately checking its composition vandalism. 2 You should take particular account of the hazards displayed by any hazardous wastes to be deposited when preparing your accident management plan.

Accident management plan

Fires

Within the landfill sector, you should pay particular attention to landfill fires.

Current understanding suggests the two primary causes of landfill fires are vandalism and poor landfill gas management.

Recommendations for preventing fires
1 You should take the following measures to minimise the risk of fires: • site security to prevent unauthorised access • prompt emplacement, compaction and covering of wastes in well-defined cells • prompt capping of completed areas • prevention of air ingress in to the waste and gas extraction and collection systems. 2 Your waste acceptance procedures should preclude the acceptance of hot or reactive wastes. 3 You should extinguish fires as soon as possible and report fires to us.

Stability

Recommendations for stability
1 You should assess the stability of your landfill. Your assessment should include: • settlement or slippage within the foundation (subgrade) beneath the landfill base or sides • slippage within the liner system • slippage at the waste/liner interface • rotational failure within the waste, or through the whole cross-section • slippage failure of the cap or of its components • effects of settlement on the landfill cap and restoration • effects of settlement on environmental management infrastructure. Your assessment should take account of the presence and movement of waste and leachate. 2 You should not analyse waste stability by ascribing to it conventional geotechnical parameters, unless the waste is homogeneous and its geotechnical properties known. This is because waste is generally a heterogeneous material subject to decomposition, consolidation, and considerable variation, both spatially and with time. You should justify any assumptions and should undertake sensitivity analysis. 3 For household waste and similar industrial and commercial waste, convenient rules of

Accident management plan

Recommendations for stability	
	thumb you may consider are: • a maximum finished slope of 1 in 4 will generally provide an acceptable factor of safety • for temporary slopes between phases of a landfill, 1 in 2 to 1 in 3 has been found to be satisfactory. However, as the biodegradable component of landfilled municipal solid waste declines and pre-treatment of waste increases in response to the Landfill Directive, such rules of thumb will require re-evaluation.
4	You should monitor stability and settlement in the construction, operational and aftercare phases.
5	Stability can be a problem at the interfaces between geosynthetics and mineral layers. When building liner systems it is necessary to construct layers of different materials, either for separate or synergistic purposes. You should consider all potential interactions between layers, both in use and under construction. You should assess the interface friction between each layer under all conditions of use, both static and dynamic, temporary or permanent.

2

Operations

The landfill life cycle

2. Operations

The concepts of the landfill life cycle and the conceptual model provide a framework that will allow you to meet the technical requirements of the Landfill and IPPC Directives in an integrated way.

The remainder of this section relates to your landfill operations

2.1 The landfill life cycle

You should consider your landfill as a continuous project, from concept, through planning, design, construction and operation to closure, aftercare and eventual permit surrender. You should use information gathered at each stage and integrate your decisions with previous and subsequent stages to continuously update your understanding of the site and the nature and impact of its operations.

The life cycle of a landfill involves three main phases:

- development - the stages from the initial concept through site investigation, planning, design and obtaining the necessary permissions
- operational - the construction (or preparation) of the landfill and the deposit of waste
- closure and aftercare - when the landfill has ceased taking waste for disposal, and restoration and aftercare maintenance measures are carried out until the permit is surrendered.

You should consider during planning and design any changes that are likely to occur over the whole life of the landfill, and make appropriate provision for these.

You should produce a long-term risk assessment for the whole lifecycle of the site at the application stage. The eventual surrender conditions should form part of your overall risk assessment for the landfill and you should consider this directly at the permitting stage (reference 42). You should put forward site specific indicative surrender criteria at the application stage as part of your hydrogeological, landfill gas and stability risk assessments.

You will need to interact with us throughout this life cycle, and agree design changes at the appropriate stages. You should include procedures for continuous review and incorporating necessary changes in the operational and post-closure phases. You should record details of revisions and amendments to the design and construction proposals and show how these relate to the project objectives.

You should recognise the objective of the legislation with respect to closure is to ensure sites remain under regulatory control until there is no longer a need for such control. We must be confident that your landfill no longer poses any pollution risk before accepting the surrender of your permit.

The landfill life cycle
Landfill design and conceptual model

When the permit is surrendered, a site may not be suitable for further development. Our acceptance of the surrender simply confirms that we consider that additional or active control measures are unlikely to be required to prevent pollution or harm as a result of emissions from the undisturbed site.

Development work which disturbs the contents of the site or which was not identified as a receptor in the surrender risk assessment will not have formed part of our decision

2.2 Landfill design and conceptual model

Design overview

In this section the term ‘design’ relates to the landform and all the engineering, operational, restoration and aftercare elements needed to create it. Your ‘conceptual model’ should describe the design, construction and operation of a landfill and the nature of baseline environmental conditions. It should also identify possible sources, pathways and receptors and the processes that are likely to occur along each of those source-pathway-receptor linkages. Your conceptual model for the landfill should cover all environmental media.

An important objective of landfill design is to return the products of waste degradation to the environment in a controlled way, at a rate the environment can accept without harm. The main mechanisms for removing those decay products are your leachate and gas management systems.

You must gain approvals for your landfill from the Waste Planning Authority (WPA) as well as us and your development of the conceptual model should therefore meet the requirements of both.

Your iterative design process is likely to include the following:

- initial concept
- pre-application discussions with us and WPA
- desk studies and fieldwork
- preparation of the planning application and environmental statement
- preparation of the permit application
- preparation of construction specifications and details of operational procedures
- modification in response to monitoring and operational experience.

Site investigation

In order to develop the site conceptual model, you will need to carry out sufficient site investigation to:

- meet the requirements of the Groundwater Directive

Landfill design and conceptual model

- establish that the site is suitable for its intended purpose
- establish baseline (background) conditions for the site
- enable an assessment of the impact of the development on local populations and the environment
- enable a monitoring programme to be developed and implemented to identify whether there are any environmental impacts from releases from the site
- develop the engineering design of the site, including the stability of the substratum
- allow design of measures to mitigate any adverse impacts.

It is essential you get sufficient information to provide a robust risk assessment and landfill design as a result of a full understanding of your conceptual model.

Recommendations for site investigation	
1	Your site investigation should comprise both desk study and where necessary, field investigations. The scale and extent of the investigations should relate to the nature of the proposed landfill (types of waste), the complexity and sensitivity of the geological and hydrogeological environment, and the proximity of potential receptors which may be affected. Since knowledge of many of these aspects will only be revealed as the investigation unfolds, any investigation should be phased. You should have clear identifiable objectives for each phase of the site investigation which should be re-appraised during and between phases.
2	You should adopt a quality approach for all site investigation activities, as part of the overall quality approach to landfill design, construction and operation.
3	Your investigations should include both the site and the surrounding areas that will be influenced by the landfill. For areas of a landfill installation which lie outside the permanent deposits of waste, reference should be made to our guidance document H5 which details the site condition report requirements (reference 10).
4	Your investigations should include the initial design of the monitoring programme, and installation of groundwater and soil gas monitoring points to allow collection of background/ base readings over the maximum practicable period of time (and in any case for a minimum of 12 months). For example, this should take into account seasonal fluctuations in groundwater levels.

Landfill design and conceptual model

Recommendations for site investigation	
5	You should undertake an accurate topographic survey for both site design purposes and for calculating void space (topographical surveys are considered in more detail in the monitoring section (see under Section 3). You should survey all borehole positions and other site features such as streambeds, springs, outcrops and exposures. Wherever possible, the survey data should be in an electronic format that can be easily used as part of the design process. For example, a computer aided design drawing file with the capability to produce an output format which can be universally read by other systems (a *.dxf* format is the most common).
6	You should consider using aerial photographs which can provide a useful means of communicating the context of the site and recording development throughout its life. Using aerial surveys may also be advantageous in areas where access is difficult.

Detailed design

The level of detail required at each stage varies according to the design elements involved. You will need to provide detail on some aspects, such as the landform at the planning application stage. For some elements, such as the in-principle construction of leachate extraction wells, you will need to provide detail in the permit application. Other detail, such as the basal drainage layout of a future phase, may be left for agreement when the time to prepare that phase approaches.

The information you provide in the permit application will be a refinement of the work you have undertaken in developing your conceptual model for the planning process. You must consider your intended method of operation in designing the site, its environmental protection measures and their phased development.
You should consider all the elements summarised below.

- profile of the final landform, (including consideration of slopes stability, visual impact, void capacity, settlement, aftercare management and waste density)
- phasing of the development
- site infrastructure, incorporating safe traffic access and haul routes, all the facilities for receiving and handling waste and administration of the landfill site
- materials requirements and materials balance
- lining system, performance (durability and monitoring), stability and relationship with leachate management systems
- groundwater and surface water management
- leachate management
- landfill gas management
- control of noise and dust
- preparatory works required prior to filling with waste

Landfill design and conceptual model

- monitoring requirements (groundwater, surface water, leachate, gas and so on)
- standards for implementation, including quality management and CQA
- closure, restoration, aftercare, after use and surrender.

Once we issue your permit, the translation of the design into the specification and drawings needed for construction purposes may require a greater level of detail.

Your design should identify the interactions between all the design elements. Your design process should consider and acknowledge the interactions between these elements. You may need to reconcile potential conflicts of priority. For example, the management of direct rainfall, surface water, groundwater, leachate, gas, particulate matter and stability are interrelated; and so dealing with risk to groundwater cannot be conducted at the expense of an unacceptable landfill gas risk. Examples of potential interactions from landfill site phasing are given in Table 1.1 Potential interactions between design elements:

Landfill design and conceptual model

Advantages of phasing	Potential interactions
Progressive use of the landfill area, so at any given time parts of the site may be in the process of being: • capped and restored • capped • actively filled • prepared to receive waste, or • undisturbed to avoid frequent and disruptive preparatory works, each phase should last 12-18 months.	May limit operational space. direction of phasing to be resolved between: • screening for visual, wind and noise • location of materials resources • preference for leachate drainage to start at lowest point • access routes – start at furthest point or travel over restoration Note: may be impracticable in deep sites.
Progressive restoration	Potential instability in part-filled void, where support from future waste is absent.
Progressive excavation of on-site materials, storage or restoration materials, and minimisation of double handling	
Minimises area required for active landfill operations and concentrates activities within a sequence of defined areas	
Staged development and restoration expenditure	Need for protection of temporary edge of lining/capping
Reduces leachate generation by minimising areas of active and unrestored tipping, and keeping them separate from clean surface water	Need to protect against leachate overflow into unlined areas
Limits delays to active gas extraction	
Progressive installation of leachate and gas controls	
May be a requirement of planning permission	Achievement of agreed landscape plan
Can reduce impact on local amenity for example visual, noise, dust, litter.	

Landfill engineering

2.3 Landfill engineering

The permit requires you to submit construction proposals for new cells and other landfill infrastructure to us. Construction of a new cell or landfill infrastructure is not allowed to start until we confirm we are satisfied with your proposal. The construction must be in accordance with that proposal unless you have agreed the change in writing with us, or the change is so minor it has no negative impact on the performance of any element of the design.

Landfill infrastructure includes any specified element of the:

- permanent capping
- temporary capping (such as engineered temporary caps, not cover materials)
- leachate abstraction systems
- leachate transfer, treatment and storage systems
- surface water drainage systems
- leachate monitoring wells
- groundwater monitoring boreholes
- landfill gas monitoring boreholes
- landfill gas management systems within the site.

You are required to submit a construction quality assurance (CQA) validation report for each new cell. No waste may be deposited in a new cell until we have confirmed we are satisfied with your CQA validation report. It remains our responsibility to inspect the new cell prior to approving its operation.

There may be circumstances where you need to implement landfill gas and other controls in a very short time scale either for safety purposes, to prevent the uncontrolled release of landfill gas or as emergency repairs to the management system. In these circumstances, you may construct the landfill infrastructure provided you submit construction proposals as soon as practicable. This does not remove the need for you to implement planned and foreseeable work in accordance with the CQA requirements set out in guidance on the management of landfill gas (reference 34).

If we do not confirm whether or not we are satisfied, or inform you that we require further information after four weeks of receipt, we are deemed to be satisfied with your proposals and CQA validation report submissions. If we are not satisfied, we must explain why the proposals are unsatisfactory so as not to delay development.

Landfill engineering

Construction quality assurance (CQA)

It is essential you adopt a quality approach to landfill engineering. Whilst construction quality assurance (CQA) techniques can't guarantee you have carried out the works in accordance with the specifications, they should give confidence you have met the following requirements:

- mechanisms are in place to ensure construction of the engineered systems will meet the standards and specifications agreed with us; and
- the design, construction and testing are well documented to provide an audit trail.

Your CQA procedures should follow the guidance given in references 17 to 27.

Recommendations for construction quality assurance	
1	You should submit CQA plans sufficiently in advance of the programmed work to allow us to consider the proposals. You should discuss your programme of works with us to agree a submission programme and approval for CQA plans.
2	You should provide us with the CVs of all office and site based CQA personnel involved in the works prior to the works commencing. You should outline the roles and responsibilities of each member of the CQA team within your CQA plan for the works. Our approval will be made on the basis of both the qualifications and the experience of the proposed CQA Inspector and we will consider the complexity of the proposed works. CQA/Design engineers while generally office based should ideally be a chartered civil engineer or geologist. The validation report should be signed by CQA/Design engineer who should be a chartered civil engineer/ geologist.

Landfill engineering

Recommendations for construction quality assurance	
3	You should submit a validation report which should include: • details of how you have complied with your CQA plan • justifications for any changes or deviations from the agreed plan • the results of all testing – this must include the records of any failed tests with a written explanation, details of the remedial action taken, referenced to the appropriate secondary testing • plans showing the location of all tests • 'as-built' plans and sections of the works • copies of the site engineer's daily records • records of any problems or non-compliance and the solution applied • any other site-specific information considered relevant to proving the integrity of the construction • validation by a qualified person that all of the construction has been carried out in accordance with the construction proposals.

Rainwater, surface water and groundwater management

Recommendations for rain water, surface water and groundwater management	
1	You should plan water management at the landfill to take into account the weather, hydrology and hydrogeology of the site.
2	You should develop a final plan for the water control infrastructure as an integral part of the engineering design and should link the plan to the site restoration plan.
3	You should undertake water balance calculations which should be based on accurate data relevant to the specific site location. You should also consider seasonal variations.
4	You should intercept rainwater running off areas outside the landfill and channel it away from construction, operational and post-closure phases.
5	You should manage rainwater coming into contact with waste and/or leachate as leachate. You should treat other rainwater from the landfill to remove suspended solids prior to use or discharge.
6	You should install temporary caps on non-operational areas and cap and restore completed areas as soon as practicable. You should protect capping against erosion and infiltration. Drains on the landfill should be able to accommodate settlement.
7	You should design the surface water drainage system to cope with predicted storm events.
8	The requirement in Annex 1(2) of the Landfill Directive to prevent groundwater from

Landfill engineering

Recommendations for rain water, surface water and groundwater management	
	entering into the landfilled waste will be interpreted in a risk-based manner. You should prevent groundwater from entering the landfill as far as is necessary to ensure there is no unacceptable risk to the stability or effectiveness of engineering controls (for example, the lining and leachate collection systems), other environmental protection measures and the environment. You should determine what constitutes acceptable risk through risk assessments that satisfy the requirements of the Groundwater Directive and explicitly address: • the geotechnical stability of the lining system, wastes and underlying geological strata • the efficacy of the leachate collection system (for example, drainage layer, pipework, pumps and abstraction chambers) • the effectiveness of any groundwater control systems (for example, drainage layers, pumps, abstraction points) • the ability to maintain operational and management control of the leachate and groundwater regimes in the long term (that is, until you surrender the permit) • the ability to effectively collect landfill gas and control landfill gas migration.
9	You should, where possible, accomplish any long-term control of groundwater by passive means such as barriers or gravity drainage.
10	All landfills should address the particular risk of direct discharge of listed substances to groundwater in the long-term. This is particularly relevant to sub- water tables where there is no natural geological barrier.
11	You should design any groundwater management system to: • accommodate the calculated flows • avoid clogging of drainage layers • accommodate discrete spring flows • accommodate anticipated settlement and overburden • allow CCTV inspection, jetting and maintenance.

Geological barrier

Recommendations for geological barriers	
1	You must have a geological barrier at your landfill.
2	The geological barrier must provide a barrier to contaminant movement that is, it must possess purifying powers (attenuative properties).

Landfill engineering

Recommendations for geological barriers	
3	The geological barrier must extend along the base and all the way up the sides of the landfill site. Your design must demonstrate the stability of any side-wall geological barrier.
4	The geological barrier must provide sufficient attenuation to prevent a potential risk to soil and groundwater. Your risk assessment must demonstrate the performance of the proposed geological barrier for a site against the requirements of the Groundwater Regulations, that is, there must be no discharge to groundwater of List I substances and no pollution of groundwater by List II substances at any stage during the life cycle of the site.
5	Your risk assessment should consider: • both the operational and post-closure phases • failure and degradation of other controls, such as the artificial sealing liner, the leachate management system and operational/management controls including groundwater pumping • likely variation of leachate concentration with time • stability and settlement • the role of the barrier in controlling landfill gas.
6	Where the geological barrier does not provide sufficient environmental protection naturally you can artificially enhance the barrier. [Note: constraints apply on major aquifers and within source protection zones II and III through our policy for the protection of groundwater (reference 5)].
7	The artificial barrier must be at least 0.5m thick. This precludes the sole use of a geosynthetic liner product to enhance the geological barrier.
8	For the construction of the artificial geological barrier you should follow the guidance on the construction of compacted clay liners (reference 25), bentonite enhanced soils (reference 24), or other appropriate guidance.

Landfill engineering

Artificial sealing liner

Recommendations for the artificial sealing liner	
1	The design of your leachate collection system must include an artificial sealing liner.
2	Your should select an artificial sealing liner on the basis that risk assessment of the overall landfill design demonstrates there is no likelihood of unacceptable discharges from the landfill over its entire lifecycle.
3	If your artificial sealing liner is a geomembrane, you should use our guidance on the use of geomembranes (reference 19).
4	Mineral artificial sealing liners are only likely to be acceptable where there is a substantial natural geological barrier. There may be circumstances where a single mineral layer can be regarded as achieving the objectives of both an artificially established geological barrier and an artificial sealing liner. If your artificial sealing liner is compacted clay you should use our guidance on compacted clay liners (reference 25).
5	Your stability assessment should take into account the interactions between the multiple layers present in the lining system.
6	Your liner systems should, in addition to being of very low permeability be stable, robust, durable and resistant to chemical attack, puncture and rupture.
7	Your design may provide robustness, durability and puncture resistance by: • the inherent strength of the liner components themselves • the combination of two or more components acting synergistically • physical thickness • protective layers.
8	You should assess the chemical compatibility of the liner materials (and, if used, any artificial support structures) with the probable waste, leachate and gas composition and temperature.
9	You should consider the effect of potential weaknesses or imperfections in the liner materials on the short and medium term performance of the liner.

Landfill engineering

Recommendations for artificial sealing liner protection	
1	Where you use a mineral liner as the artificial sealing liner, you should protect it against erosion, weathering, desiccation, vegetation and penetration. Protection can be afforded, for example, by leachate collection layers, with geotextile separation above the clay.
2	You should protect geomembranes against puncture, ultra violet degradation, thermal and localised stress, and stress concentrations, for example indentations, which can lead to stress cracking. We have produced guidance on the use of a test for determination of the effectiveness of materials used as geomembrane protection (reference 21).
3	You should select a suitable material to provide appropriate protection. A range of materials including geotextiles and mineral materials can provide this appropriate protection.
4	Where you use mineral layers for liner protection, they should be fine grained, 300mm thick or more, overlain by a separation geotextile and the leachate collection system. You should ensure that placing the protection layer does not damage or over stress the liner, in particular damage by the placement machinery itself. You should provide erosion control, particularly on sloping areas.

Leak detection

Recommendations for leak detection	
1	You should monitor the performance of the liner system in order to verify design assumptions and inform the design of future phases. This may require installing permanent or semi-permanent monitoring systems to verify design assumptions in the short to medium term.
2	You should use geophysical leak detection on all cells where the artificial sealing liner is a geomembrane, to check for defects after the installation of the leachate drainage layer and prior to depositing waste (reference 20).
3	Your risk assessment may indicate the need for a leakage interception layer within the lining system. You should consider its purpose which may be for detection, interception and removal of any leakage through all or part of the liner system, or for detection only. The system should be divided into compartments to assist in locating any significant leakage, and possibly in its remediation.

Landfill engineering

Recommendations for leak detection	
4	You should monitor any leak interception system and interpret the results carefully. For example, instances have occurred where the seepage intercepted has, on investigation, been demonstrated to be pore water expelled from the mineral liner component under the loading effect of the wastes.
5	You should consider whether land should be reserved adjacent to the landfill as a contingency against unanticipated seepage, for example, to allow the construction of interception facilities.

Settlement

You must assess the stability and settlement of the waste, the constructed landform, its foundation and the environmental management infrastructure and the interactions between them. You must demonstrate that the environmental management infrastructure will not be compromised and there will be no risk to safety or detriment to the landform over the entire lifecycle of the landfill. Refer to the technical reports on the Stability of landfill lining systems (references 31 and 32). You must demonstrate structural/physical stability over the entire lifecycle of the landfill.

Recommendations for settlement	
1	An accurate prediction of settlement is difficult because time-related settlement data are rarely available from surface measurements. The data that is available indicates long-term settlement of biodegradable waste can be approximated to an exponential curve which could result in most settlement taking place over 30 years with the majority occurring in an initial five year period. Pre-treated wastes with less biodegradable content may have different characteristics. To anticipate the effects of settlement, you should add a surcharge to the post-settlement levels, and distinguish clearly on design drawings the ultimate post-settlement levels and the surcharged levels to which each phase of the site is to be filled, capped and restored. If the depth of fill at any point is D on closure, and d ultimately, then: Settlement = (D-d) ÷ D; whereas Surcharge = (D-d) ÷ d, and is therefore a higher figure. Values of 15-25% are typical of the settlement allowance you may need to make when considering the void capacity and final pre-settlement contours of a household waste landfill.
2	Where differential settlement may occur, you should make provision to accommodate the settlement and the associated stresses, most commonly by:

Landfill engineering

Recommendations for settlement

- additional thickness of capping materials to accommodate differential movement or to allow removal of material if settlement does not occur as predicted
- irregular edges and boundaries to compensate for predicted settlement differentials.

3 You should ensure continuous surface water drainage across areas of differential settlement, for example using flexible synthetic/membrane channels.

Additional recommendations for landfilling hazardous wastes

1 Hazardous wastes are likely to be fine-grained materials such as filter cakes and ashes. This waste is likely to be less heterogeneous than domestic waste and may be granular with little cohesion. Whilst the landfill engineering may play a role in retaining the wastes initially, wastes should have at deposit, or achieve during the active management phase, sufficient mechanical strength for the creation of a sustainable landform in the long-term.

Your stability assessment should take account of the site-specific circumstances and should use geotechnical parameters appropriate to the waste material.

Capping

Your capping design should take account of:

- the balance between the requirement to manage leachate generation and the need to flush contaminants from the waste
- the containment of landfill gas
- the need to physically separate some wastes (for example, asbestos) from the environment.

You should use our guidance on capping and restoration of landfills (reference 30).

Recommendations for capping

1 Hazardous and non-hazardous landfills will normally require a cap.

2 Your capping system should contain:

- a sealing layer
- a surface water drainage system

cover soils to protect the sealing layer and drainage system.

3 You should determine the appropriate sealing layer on the basis of the hydrogeological and landfill gas risk assessments (references 43 and 34).

4 You should take into account the interactions between all the elements in the capping system in your stability risk assessment (references 31 and 32)

5 Whether your design should include a gas drainage layer will depend upon the site-specific

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Recommendations for capping
gas extraction system. In most biodegradable landfills, retro drilled landfill gas extraction boreholes are the preferred method of gas management. Gas drainage layers may have a greater role for inorganic landfills in particular landfills for hazardous waste.

Leachate management

Recommendations for leachate management	
1	Leachate levels in landfills should be set and managed in order to provide for a high level of environmental protection. You should put forward your proposals as part of your permit application. We will set a limit or limits for leachate depth in your permit.
2	You should develop site-specific action levels below the specified compliance limit. This will not form part of your landfill permit but should be contained within your environmental management system and be designed to instigate the pumping of leachate to ensure you don't breach the compliance limit.
3	You should use a water balance calculation to predict the volume of leachate produced with time.
4	A 300mm thick granular aggregate leachate drainage blanket in combination with a robust and well engineered slotted/perforated pipework system is acceptable as long as all the following minimum design and installation criteria are met
5	To ensure flow to the sump, the minimum gradient of the base of each cell should be between 1% and 2% (1 vertical to 50/100 horizontal) towards the sump

Landfill engineering

Recommendations for leachate management	
6	The drainage layer should be used along the entire base of the cell. The perimeter side slope will require a drainage system that is designed to accommodate transmission of leachate to the base of the site, thus minimising leachate head on the side slope, and provide adequate protection of any side wall lining system. The side slope drainage should be subject to risk based design and may not necessarily be the same design as the basal drainage layer.
7	The hydraulic conductivity of an aggregate drainage blanket is important in both the initial phase and the long term and is related to the grading of the material used. Environment Agency R&D Report P1-397 recommends a coarse aggregate is used to prevent biological clogging. The recommended grading of aggregate for use in a drainage layer is BS 13242:2002 20/40 aggregate, in accordance with Table 1 below. However, a finer graded 10/20 aggregate in combination with a filter geotextile on top of the leachate drainage blanket can be used where there are site specific issues. Such issues would include physical properties, lack of an available source of coarser stone within close proximity to the site and the lack of a suitable and affordable protection layer to a geomembrane (which will need confirmation via a cylinder test). The control of the grading should be via Particle Size Distribution testing on the material after placement. It should be recognised that the amount of fines may increase with handling on site. Therefore an additional allowance of 2% of material passing the smallest sieve will be allowed.
8	Any drainage aggregate should have a minimum soaked ten percent fines value of 100 kN[1].
9	Other drainage media are acceptable provided you explicitly assess the following issues and demonstrate that they are suitable for use: • chemical resistance/compatibility • strength and physical characteristics • long term hydraulic performance • permeability • transmissivity • stability • redundancy • liner protection

[1] Recommended 10% fines value to ensure that the drainage material does not break down under loading and block the drainage media.

Landfill engineering

Recommendations for leachate management	
	• fires (tyres) • compacted thickness (tyres)
10	The slotted / perforated pipes should be bedded on suitable pipe bedding material and covered with drainage material to a minimum thickness of twice the external pipe diameter
11	BS EN 1295/Modified Iowa Formula (Koerner 2005[2] or Rowe et al 2004[3])* should be used to demonstrate the deformation of the specified slotted / perforated pipe is below 5% (Bank rather than trench methodology of calculation)
12	All sections of pipes should be firmly fixed together using butt fusion or electro-fusion welding techniques. Simple push-fit couplings and hand welding techniques should not be used.
13	Pipe diameter should be a minimum of 120mm nominal internal diameter for branches and 160mm nominal internal diameter for main runs.
14	The pipe spacing should be a maximum of 30 metres or calculated using Rowe Section 2.4 (Rowe et al 2004)
15	Carbonate minerals (eg limestone and dolomite derived aggregates) are acceptable as constituents for most normal leachate drainage blankets for non-hazardous sites. Additionally, carbonate minerals are acceptable for the leachate drainage blanket in hazardous sites, so long as consideration is given to the chemical compatibility of the mineral drainage blanket and the leachate generated from the waste.
16	The as-placed pipework should be surveyed in order to confirm they have been placed to the required gradient.
17	Leachate should be drained to collection sumps located at low points from where it can be removed from the landfill for disposal or recirculation. Wherever possible, you should design the drainage system for ease of access, shorter pumping mains, and, if possible, future gravity removal.
18	You should remove leachate from the drainage collection system by:

[2] Koerner R M (2005) “Designing with Geosynthetics” Prentice Hall, New Jersey

[3] Rowe RK, Quigley RM, Brachman RWI, and Booker JR (2004) “Barrier Systems for Waste Disposal Facilities”, Spon, London

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Recommendations for leachate management

- vertical wells
- side slope risers located on the site perimeter
- by gravity drains through, say, an end bund of a valley site in a land-raise site.

19 You should install a 'target pad' in preparation for retro-drilling to replace a failed extraction well and/or monitoring point. The design of the target pad will be site specific, but normally it will comprise a significant local increase in drainage blanket thickness possibly in conjunction with some sort of liner protection material (reference 28).

20 Your design of leachate extraction wells should meet the following:

- a minimum internal diameter 600mm[4]
- walls with slots for leachate ingress only within the permitted leachate level
- air tight sealing of the top of the well
- sealing between the well and waste for at least the top two metres[5]
- appropriate strength and protection
- provision for access for CCTV and jetting of the leachate collection pipework, if relevant
- heavy, lockable, gas tight covers
- appropriate written safety procedures for entry
- designed to accommodate settlement of the waste around the extraction well and any associated deflection
- designed so as not to damage the liner below.

21 Your layout of leachate collection and monitoring wells should avoid locations that are difficult to access for monitoring and abstraction purposes. Lateral movement during waste placement and subsequent settlement is likely to result in damage to and often loss of the well. The direction of filling can also have an impact on wells. Filling against leachate wells from the same direction in each lift can result in their failure.

22 Where relevant, side slope risers should permit access for CCTV or jetting and for inspection. For this, and for pump access, your side slope risers should be at a continuous gradient over their length and should not follow, for example, any intermediate benches in the landfill side slope. You should assess the effects of the side slope riser on the stability of the adjacent liner system, together with the need for

[4] Recommended diameter, so that in the event of a failure, secondary pipework may be fitted within the annulus, or re-drilling undertaken within existing pipe work at the same location.

[5] Recommended depth to prevent air ingress to the site that may impact on gas management and to prevent odours.

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Recommendations for leachate management

additional protection. Side slope risers should be sealed near the surface, that is, at least the top two metres, to prevent air ingress into the landfill. Your design should allow for the use of permanent buried pipework as soon as is practicable to carry leachate from the removal manholes to the treatment or disposal facility. Pipework outside the lined area should be constructed to be leakproof and integrity assured.

23 You should consider the measures required to treat contaminated water and leachate to the appropriate standard prior to discharge (irrespective of whether leachate is treated on or off site). You should include the measures described below:

- assessment in accordance with Environment Agency H1 guidance (reference 7)
- the necessary wastewater treatment system for the activity including any off site treatment where appropriate; the identification of the main chemical constituents of the treated effluent (including the make-up of the COD) and assessment of the fate of these chemicals in the aquatic environment. This applies whether treatment is on or off-site
- contingency plans for leachate management in the event of breakdown of various components.

monitoring of leachate quality in accordance with guidance on monitoring of landfill leachate, groundwater and surface water (reference 16) and the permit.

24 You should design, build and operate any leachate storage and treatment lagoons in accordance with the Guidance for the recovery and disposal of hazardous and non hazardous waste (SGN5.06).

25 For a biodegradable waste landfill, you can consider leachate recirculation into the waste mass as part of the leachate management system, provided:

- there is an effective leachate drainage and extraction system in the relevant cells of the landfill
- leachate levels are under control and are being managed in the relevant cells of the landfill
- landfill gas infrastructure with adequate capacity is in place to extract, collect and treat the volume of landfill gas from the part of the landfill where recirculation is taking place
- leachate composition will not impede stabilisation processes within the landfill
- where necessary the leachate is treated prior to re-introduction to the waste
- the recirculation system is designed to avoid preferential pathways forming within the waste, and to ensure an even distribution through the waste
- you have designed the recirculation system to prevent odour or amenity problems

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Recommendations for leachate management
• you have designed the recirculation system to prevent air ingress into the landfill that may impact on the operation of the active landfill gas extraction system.

TABLE 1
Grading of aggregate drainage material from BS EN 13242

British Standard Sieve Size (mm)	**Percentage Passing (%)**	
	20/40	10/20 **(Note 1)**
63	98 to 100	-
40	80 to 99	100
31.5	20 to 70 (+/- 15)	98 to 100
20	0 to 20	80 to 99
14	-	20 to 70 (+/- 15)
10	0 to 5	0 to 20
4	-	0 to 5

Note 1: If the 10/20 graded stone is proposed it must be accompanied by a filter geotextile over the stone. A specification for the geotextile filter is given in table 2 below.

TABLE 2

Property	*Test*	*Acceptance*
Polymer		Polypropylene
Geotextile Construction		Non-woven - mechanically bonded
Marked		CE
Tensile strength	EN ISO 10319	Within manufacturers publ'd parameters
Elongation at max load	EN ISO 10319	Within manufacturers publ'd parameters
Static puncture (CBR)	EN ISO 12236	3300 N min.
Dynamic perforation	EN ISO 918	Within manufacturers published

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resistance (Cone Drop)		parameters
Characteristic opening size O_{90}	EN ISO 12956	50 to 120 µm
Water permeability normal to plane	EN ISO 11058	>40 l/m^{2}s
Thickness	EN 964-1	>1.5 mm
Mass per unit area	EN 965	>300 g/m^2
Durability	See Annex B of EN13252 OR German robustness class (GRK) 5	
Resistance to weathering (UV)	EN 12224	> 1 month
Resistance to chemical ageing	EN ISO 12960, EV ISO 3438 or ENV 12447	Within manufacturers published parameters
Resistance to microbiological degradation	EN 12225	Within manufacturers published parameters

NOTES:

1 A method statement shall be provided which shall include as a minimum:

- the method of joining/overlapping adjacent rolls of geotextile
- the direction of rolls with respect to eventual placement of waste
- where a geotextile is to be placed well in advance of waste, test results should be provided demonstrating adequate performance before waste covers geotextile (i.e. test results showing, say, six months before onset of uv degradation allows geotextile to be left exposed for that period and if still uncovered samples require retesting to demonstrate compliance before covering with waste.

2. The geotextile is an important part of the drainage system and requires full supervision, whether at the time of cell construction or in phases as waste is placed and should be adequately addressed in the CQA Plan.

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3 For validation report purposes the manufacturing quality assurance data needs to be reported if it can be matched to the specific rolls of geotextile used. If this is not possible, on site CQA testing needs to be carried out and reported.

Landfill gas management

We will regulate the management of landfill gas in accordance with the following principles:

- active extraction as early as possible
- passive venting is not acceptable
- maximising extraction efficiencies
- emission limits on all point source releases
- emission monitoring of point and diffuse sources
- ambient air monitoring on a risk basis..

Recommendations for landfill gas management
1 You should undertake a landfill gas risk assessment at an appropriate level of detail based on the guidance on the management of landfill gas (reference 34). This is likely to require the application of a Tier 2 or Tier 3 risk assessment. You should use probabilistic models of landfill gas generation such as GasSim to predict gas generation, screen out risks and carry out air dispersion modelling of emissions.
2 You should develop a landfill gas management plan based on your site specific risk assessment. You should refer to the guidance on the management of landfill gas (reference 34) which gives detailed guidance on the required scope and content of the landfill gas management plan.
3 Where your risk assessment identifies landfill gas will be generated, your site will need the following elements to manage it: • containment - barriers to prevent sub-surface migration and minimise surface emissions of landfill gas • collection - an active gas extraction system to achieve the maximum practicable collection efficiency. • utilisation, flaring and treatment - a system of combustion or other treatment processes meeting the emission limits for that process. Treatment of the gas stream pre or post combustion will be a site-specific issue based on the precise composition of the gas stream.
4 You should design the gas extraction system to maximise the quantity of landfill gas

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Recommendations for landfill gas management	
	collected and to prevent landfill gas escaping beyond the containment system. You should not design the gas extraction system to attempt to extract gas from outside the waste body or the containment system.
5	Pumping trials provide information on how much gas can practically be extracted from the waste. You should use this information to validate your predicted gas generation rates, your site specific risk assessment, and also to optimise the extraction well spacing prior to installing the landfill gas extraction scheme.
6	You should design and operate cells to minimise the period before you can install active gas extraction (as well as for water balance purposes). Areas of the site that are temporarily capped should have temporary or sacrificial gas extraction installed. Depending on your site specific risk assessment, gas extraction may be required on operational areas of the site to control fugitive emissions.
7	Leachate recirculation can increase landfill gas production rates and must take place as part of a controlled landfill gas and leachate management strategy. We will not permit leachate recirculation until the landfill gas extraction system is in place to collect and treat the gas generated. Your design of leachate recirculation systems should minimise the risk of air ingress into the body of the waste.
8	You should design the landfill gas collection pipework and extraction system to adequately deal with the predicted volume and flow-rate of landfill gas produced. The collection pipework should be laid at an appropriate fall to allow condensate to drain freely and prevent blockage or restriction of gas flow within the transmission pipework. You should ensure adequate provision to de-water the system and drain the condensate back into the waste mass or leachate treatment system, either by gravity or a pumped system. You should not drain condensate across the restored surface of the landfill site.
9	The capacity of your treatment system should be sufficient to deal with the volume of gas generated at the landfill. Where you propose utilisation, the flaring capacity should be sufficient to treat all the gas when utilisation equipment is off line. Where there are a number of gas engines the flaring capacity should be such that it can deal with any plausible combination of off line engines (that is, a wide range of gas flows). This may require more than one flare. In the event of an engine going off line, the landfill gas flare should automatically ignite and flare the gas. The engine management system should include telemetry to inform you of any engine failure.
10	We will not permit the operation of ‘open’ flares except for emergency or test purposes.
11	You should review your landfill gas management plan and site specific risk assessment on an annual basis. More frequent review will be required if you change how you manage landfill gas on site, such as:

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Recommendations for landfill gas management

- an increase or decrease in gas extraction
- change in waste streams
- introduction of leachate recirculation
- changing the number of engines
- changes in the trace component analysis of the gas
- odour issues at the site.

12 Your annual review should aim to optimise landfill gas extraction by:

- estimating gas production
- validating your assumptions in the risk assessment using site-specific data, especially engine and flare emission data, and trace component analysis of the raw landfill gas
- reviewing the monitoring and reporting of gas volumes collected and treated
- reviewing the monitoring of surface fluxes of landfill gas and comparing the collection efficiency against an 85% benchmark (see our guidance on the management of landfill gas –reference 34).

13 We will set emission limit values in your permit for flare and engine emissions (based on references 36 and 37). Your site-specific risk assessment (i.e. local air quality) may require additional parameters or more stringent emission limit values to be included in the permit.

For landfill sites where the engines are unlikely to meet the emission limits, you should use guidance on the potential for pre and post combustion clean-up based on a cost benefit appraisal (reference 40) to determine the appropriate measures.

14 Your design of the landfill gas collection infrastructure should take account of potential air ingress and a programme of inspection and maintenance of the infrastructure should form part of your landfill gas management plan. A major cause of air ingress is excessive suction being applied to the collection infrastructure through over-abstraction of landfill gas. You should design your landfill gas extraction schemes to operate with a maximum extraction pressure and your procedures should ensure that the system operates within this limit.

15 Hot spots and fires can be caused by air ingress into the site. Extinguishing fires and cooling hot spots can be extremely difficult. Preventative measures and early detection are the best options to control the risk. Early detection can be achieved through routine monitoring of carbon monoxide and gas temperature within the body of the waste and in the landfill gas collection infrastructure. However routine temperature monitoring at the gas well head can be quite onerous and result in disruption of the landfill gas extraction system.

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Recommendations for landfill gas management

Therefore, you should undertake routine monitoring of carbon monoxide to monitor possible hot spot development. You should undertake temperature monitoring as part of further investigations, when levels of carbon monoxide indicate there is a possible problem. The levels of carbon monoxide and temperature can vary depending on the landfill characteristics, so you should establish background levels of these indicators.

You should carry out monitoring for carbon monoxide, using handheld instrumentation, during balancing of the gas extraction system. The presence of hydrogen gas and hydrogen sulphide gas can cause interference in handheld instruments measuring carbon monoxide; therefore you should also measure the concentrations of these interfering gases during routine monitoring. You should investigate any increase above background levels using laboratory analysis to confirm carbon monoxide levels. You should carry out routine monitoring at the well head wherever possible, and at such a frequency so that you establish a baseline trend. Your landfill gas management plan should include details of the frequency and assessment levels for carbon monoxide monitoring and details of likely further investigations and actions should the assessment level be exceeded. Where no background concentration of carbon monoxide is available, then a carbon monoxide concentration > 100 ppm[6] should trigger further investigation.

16 Landfill gas poses a risk of fire and/or explosion if not managed correctly. The Dangerous Substances and Explosive Atmospheres Regulations 2002 apply to landfill sites where landfill gas is present. You will need to carry out a risk assessment to identify hazardous zones and apply control measures to minimise the risk within those zones. The Environmental Services Association has produced a series of Industry Codes of Practice that provide detailed technical guidance on applying these regulations to landfill sites.

[6] This figure is derived from Science Report: SCO10066 'Review and Investigation of deep-seated fires within landfill sites.' This referred to >25ppm however this was considered to be too tight given possible interference on handheld instruments. 100ppm was chosen as this should be distinguishable above any background or interference.

Landfill engineering
Waste acceptance

Landfills for hazardous wastes

The waste acceptance criteria for hazardous wastes limit the organic content and hence limit acetogenic and methanogenic processes, although low levels of methane production may be found at some of landfills for hazardous waste.

Volatile organic compounds (VOCs) may be present in hazardous wastes such as contaminated soils, but the waste acceptance criteria limit on organic content, together with the requirement for treatment, are likely to limit VOC concentrations.

Production of gases such as carbon dioxide, ammonia and hydrogen sulphide is possible by chemical reaction. Production of hydrogen by reaction with water is known to occur from some wastes. If generation is significant, such wastes may be prohibited as highly flammable (hazard H3A).

Unless chemical reactions take place between wastes, there is unlikely to be a significant pressure differential between the landfill and the environment. It is therefore considered that it is likely that concentrations and emissions will be low.

Recommendations for landfill gas management at landfills for hazardous wastes	
1	You should incorporate gas migration barriers and gas collection systems/layers into site designs for landfills for hazardous waste. Where landfills are proposed below the ground, you should consider the durability of liners and their permeability to the predicted gases.
2	You should collect landfill gas from landfills for hazardous waste for treatment. We don't consider passive venting to be best practice.
3	You should design the treatment method for the collected gases on the basis of the expected composition, and sustainability in terms of inputs of materials (such as absorbents or reactants) and energy.
4	You should consider carefully the potential of the proposed waste mix for emission of gases. If you doubt your ability to control emissions in a sustainable way, you should consider pre-treating the wastes and or the mix of wastes to eliminate the potential for emissions.

2.4 Waste acceptance

The Landfill Directive and associated Council Decision provide detailed technical measures for waste acceptance. Government guidance on the Landfill Directive (reference 3) explains the requirements. Our guidance EPR LFD1, (reference 5) expands on the Government guidance and you should refer to both

Waste acceptance

documents. You should also refer to guidance on wastes destined for disposal in landfills (reference 12) and guidance on sampling and testing to meet landfill waste acceptance criteria and procedures (reference 13)

Waste Acceptance Criteria (WAC) and Waste Acceptance Procedures (WAP) are required to ensure that:

- wastes accepted are correctly described, coded and classified to ensure that hazardous wastes, stable, non-reactive hazardous wastes (SNRHW) and non-hazardous wastes are disposed of at the correct class of landfill
- wastes accepted are not prohibited and have undergone appropriate treatment (where necessary) as required by the Landfill Directive and Council Decision (2003/33/EC)
- appropriate limits are placed on the waste types and composition acceptable at the landfill
- the composition and behaviour of the waste is understood to an appropriate level and procedures are in place to control waste inputs to a landfill.

More details are available in our 'guidance on waste destined for disposal in landfill', (reference 12)

Where wastes are temporarily stored in a quarantine area, you should follow our guidance on storing and handling waste (Recovery and disposal of hazardous and non –hazardous waste – reference 14)

The general requirements contained in the permit that implement the Landfill Directive bans and waste acceptance criteria, will override any waste types that have been included in your permit.

Recommendations for waste inspection

1 You must undertake a visual inspection at the landfill entrance unless it is not **practicable** to see the waste due to the vehicle or container in which the waste is delivered. Visual inspection is not **usually practicable** where the waste is delivered in:

- a front end loader
- a rear end loader
- compaction container
- road sweeper collector
- a sheeted container
- any other enclosed vehicle where there is no access for inspecting the waste without unloading the vehicle.

In these circumstances you should check the delivery vehicle is consistent with vehicle type normally used for the waste described in the documentation. If for whatever reason you are concerned or suspicious about the nature of the waste, you should make a particular effort to complete a visual inspection at the landfill entrance. Where the waste is not consistent with the description provided, you should quarantine the load

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while you carry out further checks, or alternatively refuse the load.

At in-house facilities waste may be inspected at the point of dispatch.

2 You should visually inspect all waste at the point of deposit using staff who are:

- aware of the waste description for each load they are inspecting
- familiar with the wastes permitted for disposal at the landfill.

You should have procedures in place to allow the staff inspecting the loads to make detailed queries about the wastes that are permitted at the landfill including information on basic characterisation and compliance testing.

Where the visual inspection of the waste identifies the waste is not consistent with the description provided for the waste or is otherwise not permitted at the landfill, you should ensure the load of waste is:

- reloaded on to the delivery vehicle
- removed to a designated quarantine area.

The waste should not be accepted for disposal at your landfill.

3 Where you refuse wastes for disposal at you landfill, they should be removed by the delivery vehicle and you should make a record of this. Where it is not possible for the waste to be removed by the delivery vehicle, you should store the wastes in a quarantine area and remove them as soon as possible.

Recommendations for landfill of hazardous waste

4 In addition to compliance with waste acceptance criteria, you should also consider:

- any site-specific limitations
- the physical parameters
- testing of the hazardousness (that is, the concentration of constituents causing the hazard) of the waste, to assess any precautions to be taken to protect the environment or human health.
- the compatibility of the wastes accepted with other wastes in order to prevent any adverse reactions such as gas emissions or mobilising leachable constituents, and with the landfill engineering materials.

5 Having regard to the hazards prohibited by the Directive and to the limitations on organic content and pH set by the Waste Acceptance Criteria, the waste interactions you should consider are:

- solubilisation of metals by interaction with alkalis or ligands
- generation of low levels of gases by interaction of alkalis and other wastes, or of moisture with other wastes.

Waste acceptance

You should consider the possible interactions between wastes and landfill engineering materials.

Waste handling and placement

Recommendations for waste handling

1 Ensure every load is visually inspected by personnel trained to recognise waste that requires special handling (see point 5 below).

2 You should design the size of the working area to minimise the potential for fugitive releases.

3 You should level and compact waste as soon as it is discharged at the working area.

4 You should ensure waste is covered as soon as practicable. Guidance on using daily cover is given in separate Environment Agency guidance (reference 29). Any cover materials you use should meet the objectives of landfill cover set out in the guidance.

5 Difficult wastes - Your risk assessment should identify any wastes with characteristics requiring a particular method of handling at the site which is not part of normal day to day procedures. Typical examples are:

- finely particulate material
- empty containers
- very large objects
- sludges
- very light materials, for example, expanded polystyrene
- odorous wastes.

You should consider a pre-treatment method to reduce the handling difficulties posed by such wastes.

Additional considerations for landfill of hazardous wastes

6 You should determine the need to cover moist, fine-grained wastes at landfills for hazardous wastes on a site-specific basis taking into account your particulate matter risk assessment and the landfill gas and odour assessments. Where relevant, you should consider the need to prevent exposure to the waste on the site and the need to minimise the risk of fires.

Closure and aftercare

2.5 Closure and aftercare

Maintaining a closure and aftercare management plan throughout the life of a landfill is a requirement of the Landfill Directive (Article 13).

Closure is an ongoing process between the time when a site is 'closed', that is, it has ceased accepting waste for disposal and 'definite closure', that is, when we agree the site may enter the aftercare phase.

We have produced separate guidance on landfill closure in our 'Understanding the Landfill Directive for Environmental Permitting' Regulatory Guidance Series No. LFD1 (reference 5).

Recommendations for your closure and aftercare management plan
1 Your design should minimise risks during decommissioning. Designs for parts of the installation outside the landfill area should ensure that: • underground tanks and pipework are avoided where possible (unless protected by secondary containment or a suitable monitoring programme) • there is provision for the draining and clean-out of vessels and pipework prior to dismantling • insulation is provided that is readily dismantled without dust or hazard • materials used are recyclable (having regard for operational or other environmental objectives)
2 Your site closure plan for parts of the installation outside the landfill area should include: • either removing or flushing out pipelines and vessels where appropriate and their complete emptying of any potentially harmful contents • plans of all underground pipes and vessels • the method and resource necessary for the clearing of any lagoons • the removal of asbestos or other potentially harmful materials other than from the landfill unless agreed that it is reasonable to leave such liabilities to future owners • methods of dismantling buildings and other structures • testing of the soil to ascertain the degree of any pollution caused by the activities and the need for any remediation to return the site to a satisfactory state.
3 You should review your site closure plan at least once every four years. Other triggers for reviewing your site closure plan include any proposed changes to the phasing of the landfill. You update the plan as material changes occur.

Closure and aftercare

4 Monitoring plays a vital part in determining the performance of the landfill against any assumptions made. Your annual reviews should consider the progress made towards the initial criteria for surrendering your permit. You should review the criteria for surrender of the permit at least once every four years, including the following factors:

- quality and quantity of leachate
- generation, flow and concentration of gas
- trace composition of the gas
- potential for leachate or gas to be generated in future
- physical stability of the waste and associated structures
- presence of particular problem wastes which could present a risk in the future.

Another trigger for reviewing the surrender criteria would be where the annual review of monitoring data against the assumptions in the risk assessment indicates a significant deviation from the expected performance of the landfill.

3

Emissions and Monitoring

Emissions to water, air and land Fugitive emissions

3. Emissions and monitoring

3.1 Emissions to water, air and land

This section builds on the information relating to emissions and monitoring provided in earlier sections.

The limits set in permits are the compliance limits above which we consider pollution of the environment to be occurring. In some cases (for example, landfill gas emissions from flares and engines, emissions to groundwater) we will allow a level of uncertainty based on other guidance.

Emissions to groundwater
The permit provides conditions 3.1.4 to and 3.1.7 to address the requirements of the Groundwater Regulations.

You should refer to our guidance 'Hydrogeological Risk Assessment for Landfills and the Derivation of Control and Trigger Levels (LFTGN01) (reference 43)' Environment Agency 2003, for the setting of trigger levels in the permit. Notwithstanding our advice in LFTGN 01, we will specify trigger levels for emissions into groundwater in Schedule 4 of your permit. That part of the LFTGN 01 has been superseded by our charging scheme that allows 'administrative' variations for no charge, where appropriate.

3.2 Fugitive emissions

Within this sector, you should give particular care to the following.

Fugitive emissions

Particulate matter

Recommendations for particulate matter control – dust and aerosols
1 You should have procedures in place to deal with particulate matter arising from: • the placement of wastes • traffic on site roads during periods of dry weather • site preparation and restoration activities • surface emissions • carriage of dust/mud onto the highway.
2 Your abatement procedures should take into account the following issues: • abatement of particulate matter at the source of generation is likely to be more effective than suppression of particulate matter once they have become airborne • particle size is very important - coarse particles have much greater settling rates than finer particles: coarse particles will settle out as deposited dust quite close to the source; whereas fine particulate matter may remain airborne for longer periods and travel much greater distances. These are implicated more in health exposure impacts. There is no sharp dividing line between the sizes of suspended particulate matter and deposited particulate matter, although particles with diameters >50 mm tend to be deposited quickly and particles of diameter <10 mm have an extremely low deposition rate in comparison • many dust-suppression techniques are ineffective for the finer particles biological activity - Much particulate matter (solid or liquid droplets) from some landfills is biologically active. Biological aerosols (bioaerosols) consist of finely divided biological organisms suspended in air. These aerosols can vary in size from 0.5 to >100 µm and can occur as aggregates, as droplets or attached to inert dust particles. Bioaerosols are complex in nature, and may include: viruses, bacteria, actinomycetes, fungi, enzymes, endotoxins, mycotoxins and glucans. They can affect organisms by infection, allergy, toxicity, pharmacological and other processes. Bioaerosols are most likely to be formed when degrading waste is disturbed.
3 Your site design should minimise the area left unrestored. Restoration should take place as soon as possible following the end of waste disposal in a cell or phase.

Fugitive emissions

4	You should extend surfaced site roads as far as possible to the tipping face and should make them available for as long as possible. You should maintain surfaced site roads and keep them in a clean condition.
5	You should control the movements of site traffic including restrictions on routes and speeds.
6	You should locate wheel washers far enough from the site entrance to allow any residual debris to be deposited within the site.
7	You should provide dust suppression including the availability of 'bowsers' and water supplies. You should not use leachate for dust suppression.
8	You should develop particulate monitoring programmes for the categories of particulate matter identified in M17 (reference 11). The waste streams and substances identified in the selection of appropriate Environmental Assessment Levels (EALs) (see M17 and H1 references 11 and 7) would form the basis for the monitoring of hazardous substances. The monitoring programmes should be reviewed until the appropriate frequencies and parameters can been determined on a site specific basis.
Additional considerations for the landfill of hazardous wastes	
9	The placement of hazardous fine-grained materials poses a potential risk of wind-blown dust unless control measures such as primary cover or wetting are used. You should undertake a risk assessment on cover and wetting taking account of the specific waste types and receptors. You should also consider the alternative approach of treating the waste to solidify or pelletise it.

Litter

Litter means any wind-blown material other than particulate matter. You must have measures in place in order to:

- prevent litter forming by controlling potentially wind-blown materials
- capture litter that is generated
- manage accumulations of litter within the installation
- collect litter from beyond the boundary of the installation.

Fugitive emissions

Recommendations for litter control
1 You should manage accumulations of litter within the site and prevent litter escaping from the site.
2 You should manage litter generation through the following measures: • instructions to ensure incoming waste remains sheeted for as long as possible prior to emplacement • provision of an emergency tipping area to allow discharge of light waste within a secure litter enclosure during adverse weather; this may be a permanent fixture or mobile • adequate compaction during waste emplacement • adequate covering of wastes following emplacement • minimising the extent of the active tipping area • adequate plant on active phase for placement, compaction and covering of waste • ensuring the adequate supply of daily and intermediate cover material • daily meteorological monitoring, as part of the daily and weekly operations • instructions to ensure the full discharge of a vehicle discharging waste at the site, to prevent any waste retained in the vehicle after tipping being subsequently released • closure of the site to specific or all waste types during adverse weather conditions, for example high winds.
3 You should prevent litter escaping the site through the following measures: • considering prevailing wind direction and strength and the proximity of receptors when designing the filling development and sequence, this may require a risk assessment approach • installing permanent and mobile litter fences around the active area • installing temporary bunds immediately adjacent to the tipping area • regular inspections and collection of litter around the site boundary and beyond; specifically, ditches, haul roads, water courses • deploying additional temporary personnel to collect litter, as deemed necessary from inspections and monitoring.

Fugitive emissions
Odour

Mud on the road

Recommendations for preventing mud on the road	
1	Your management system should include the following measures to prevent mud escaping from the site, to prevent potential accident hazards, dust and other amenity issues. • effective wheel and body cleaners to remove mud and debris from vehicles prior to them leaving the site • maintenance (for example, regular water changes for wet systems) of wheelwash equipment • supervision of the use of wheelwash to ensure that vehicles use the equipment correctly • main site roads maintained in a mud free condition by employing a mechanical sweeper/washer • sufficient distance on surfaced site roads between haul roads and any wheel wash facilities • monitoring of site road between final wheel wash and public highway • monitoring of public highway.
2	In the event that mud or other debris is carried onto the public highway, you should erect warning signs on the highway to inform users of the potential hazard following approval by the highway authority.
3	You should employ road sweepers immediately to clean the affected area.

3.3 Odour

Getting the Basics Right' identifies odour as a key issue for landfills for biodegradable waste. Odour is typically associated with trace components in landfill gas, the handling of odorous wastes and unsuitable emplacement and inadequate covering of biodegradable wastes. Given the fugitive nature of odour emissions, you should concentrate on preventative measures relating to landfill gas management (see section 2.3.9) and waste acceptance and emplacement. For installations where there is a significant risk of odour (including all landfills for biodegradable waste), reference must be made to our guidance document H4 (reference 9).

Odour

Within the landfill sector, you should give particular care to the following.

Recommendations for odour control

1 You should have procedures to deal with:
- waste materials, such as wastes from transfer stations, which have started to decompose prior to landfilling
- old waste disturbed by digging
- malodorous wastes
- agricultural and sewage treatment residues
- leachate and leachate treatment systems
- landfill gas.

2 You should have procedures in place to maintain a description of the types of odorous substances deposited and generated (intentional and unintentional). This should include:
- the treatment applied before landfill, which should limit wastes which are inherently odorous
- the distinction between wastes which are inherently odorous where the impact is likely to be more immediate and those wastes which may give rise to odour because of microbiological action in the landfill (organic or inorganic).

3 You should undertake a regular odour impact assessment. The impact assessment should cover a range of reasonably foreseeable odour generation and receptor exposure scenarios and the effect of different mitigation options. Your assessment should include point sources (such as flares) as well as linear or area sources (tipping faces, cracks in the cap).

4 You should ensure:
- sulphate wastes are disposed of in cells in which biodegradable waste is not accepted (reference 12)
- there is co-ordination between the gatehouse staff and staff at the tipping face where known odorous wastes are being accepted
- the potential for odours during the excavation of waste or removal of cover, (for example, during the installation of gas wells, or for other operational needs) is assessed.

Odour

Recommendations for odour control

5 You should:

- keep tipping areas as small as possible
- cover waste as soon as possible
- design, construct and maintain intermediate capping to prevent the possible release of odours.

6 You should:

- implement an effective landfill gas management plan (see Section 2.3.9) in conjunction with good operational practice (such as not leaving odorous waste uncovered) to prevent such releases
- ensure full containment of the waste, including temporary and/or phased capping of the site
- ensure landfill gas control systems are well constructed, operated and maintained.
- consider point source emissions such as those from landfill gas flares in selecting and assessing the control system
- install active landfill gas extraction as soon as possible to minimise the release of uncontrolled landfill gas emissions.

7 You should:

- use an enclosed leachate treatment operation where the proximity of the operation to a receptor is likely to cause an odour problem
- provide enclosed leachate storage where the proximity of the storage to a receptor is likely to cause an odour problem
- effectively seal leachate sumps/wells/side wall drainage systems (retaining any necessary access for monitoring and maintenance).

Noise
Pests

3.4 Noise

Within this sector, you should give particular care to the following.

Recommendations for noise and vibration control	
1	You should ensure regular maintenance of the access roads to repair ‘pot-holes’; this serves to significantly reduce noise generated by empty vehicles.
2	Your design criteria of enclosed landfill gas flares should include noise reduction.

3.5 Pests

Within this sector, you should give particular care to the following.

Recommendations for pest control

1 You should have procedures to deal with the presence of scavenging birds which should consider:

- the deposit of excrement and scraps of food on mobile plant and vehicles on-site, reducing driver's visibility and damaging nearby property
- bird-strike damage to aircraft
- the introduction of pathogens to nearby water bodies, crops and animals
- the introduction of alien species to sensitive local habitats.

2 The measures you use to mitigate bird nuisance should include the employment of good landfill practice, with prompt disposal and compaction, working in small active areas with progressive covering of waste, and netting, together with the use of bird scaring techniques. These measures include:

- flying birds of prey over the site
- bird kites mimicking birds of prey
- shell crackers - containing flare and bangers
- rope bangers
- gas cannons
- scarecrows - fixed or mobile
- amplified recordings of bird distress calls (species specific)
- electronic sounds imitating calls of distress
- bird corpses or dummies.

Note: Measures involving explosions or distress calls may have an adverse

Pests

Recommendations for pest control	
	environmental impact in terms of noise and may scare desirable species living in the vicinity of the site.
3	You should maintain a log of techniques employed to demonstrate compliance with requirements and as part of your performance monitoring system. The log will also assist you in assessing the effectiveness of the different methods.
4	There are advantages and disadvantages to all of the methods and the degree of effectiveness of any method may deteriorate with time and may need to be changed regularly. You should periodically review the measures you use.
5	You should take into account the aviation safety standards introduced by the International Civil Aviation Organisation in 2003[7]. One of these standards relates to bird hazard reduction at, or in the vicinity of aerodromes, particularly large numbers of flocking birds feeding at landfill sites.
6	You should use the following measures to deal with pest infestation: • effective site management involving prompt emplacement, compaction and covering of wastes in well-defined cells, intermediate capping and prompt capping of completed areas • ensuring previously employed waste is not disturbed, exposed or moved • regular visits by pest control contractors or fully trained operatives • inspection and treatment of areas where rats live, for example sewers, culverts and drains.
7	Fly infestations commonly arise from waste which has been awaiting collection for some time. You should have procedures in place to prevent or limit the acceptance of such wastes. You should reduce the risk of infestation by prompt burial of such wastes in order to interrupt the reproductive cycle of the fly. You should consider the potential for fly infestation to develop if engineering works require waste to be excavated.

[7] Convention on International Aviation 1944 (The Chicago Convention) Annex 14, Amendment 27/11/2003.

Monitoring

3.6 Monitoring

Monitoring the performance of the site infrastructure, waste mass and its surroundings provides the basis for your management decisions about the need for, or implications of changes to any aspect of these over the entire life-cycle of your landfill. Monitoring programmes may have several objectives and you should review them on a regular basis to ensure you are meeting them. Your monitoring should:

- demonstrate the landfill is performing as designed and in accordance with risk assessment predictions
- provide reassurance that management and control systems are preventing pollution of the environment (by referring to a pre-established baseline)
- meet the control and monitoring requirements of legislation
- demonstrate compliance with assessment levels and compliance limits set in your permit
- indicate where further investigation is required and where risks are unacceptable, the need for measures to prevent, reduce or remove pollution
- identify when a site no longer presents a significant risk of pollution or harm to human health.

You should use our Guidance on the Monitoring of Landfill Leachate, Groundwater and surface water (reference 16) and Guidance on the Management of Landfill Gas (reference 34). Monitoring and control procedures for waste acceptance, landfill gas combustion, particulate matter, noise and odour are covered elsewhere in separate Environment Agency guidance documents (references 8, 9, 11, 12, 13, 16, 33, 35, 36, 37 and 38).

You should consider the requirements of all the monitoring programmes from the early development of your conceptual model. It is essential you undertake baseline (or background) monitoring concentrations prior to infilling in order to assess changes in the environment associated with the site.

Ongoing monitoring is an essential and integral part of the risk assessment approach to landfill management. Your risk assessment will have identified receptors and pathways and you will have designed the landfill to provide appropriate mitigation measures. One of your objectives of monitoring should be to determine whether the assumptions made in the conceptual model were correct and whether the mitigation measures are performing to specification.

Monitoring

. Recommendations for monitoring

1 You should design your monitoring for a specific purpose and it must be fit for that purpose. For example, combined gas and groundwater monitoring boreholes are **not** recommended due to conflicts between the objectives of the monitoring (for example, depths of screened portions of the borehole).

2 You should review the position and construction of monitoring points during the design of the main (and any supplementary) site investigations and later during the regular review of monitoring data. If necessary, you should upgrade the monitoring points to reflect the design proposals.

3 You should use the monitoring data gathered during your operation of the site to review the validity of your conceptual model and the design assumptions you made during the planning and development processes. You should undertake this interpretation of monitoring data on at least an annual basis, and should revise your conceptual model and monitoring plan accordingly.

4 Assessment levels and compliance limits form the basis of emission control and assessment at landfill sites. You should have procedures in place with regard to the following:

- **assessment levels** are criteria relating to specific parameters we use to determine whether a landfill and its pollution control systems are performing as designed. They are levels intended to help identify the development of adverse, or unexpected trends in emissions. Such trends may results from failure of site engineering or management, or from variations between actual conditions and those assumed within the conceptual model
- assessment levels for groundwater are called ‘control levels’ in the Landfill Directive
- assessment levels should be treated as an early warning system to enable you to implement appropriate investigative or corrective measures, particularly where there is potential for a compliance limit to be breached
- **compliance limits** are limits given in a permit for specific parameters. These are concentrations at which significant adverse environmental effects and/or breaches of legislation have occurred
- compliance limits for groundwater are called ‘trigger levels’ in the Landfill Directive.

5 You may need to undertake environmental monitoring, for example, when:

- there are vulnerable receptors
- the emissions are a significant contributor to an Environmental Quality Standard (EQS) that may be at risk

Monitoring

. Recommendations for monitoring

- you are looking for departures from standards based on lack of effect on the environment
- to validate modelling work.

6 Where you do need to undertake environmental monitoring, you should consider the following in drawing up proposals:

- determinands to be monitored, standard reference methods, sampling protocols
- monitoring strategy, selection of monitoring points, optimisation of monitoring approach
- determining background levels contributed by other sources
- uncertainty for the employed methodologies and the resultant overall uncertainty of measurement
- quality assurance (QA) and quality control (QC) protocols, equipment calibration and maintenance, sample storage and chain of custody/audit trail.
- reporting procedures, data storage, interpretation and review of results, reporting format for the provision of information.

7 You should establish and maintain a network of stable, permanent survey control stations to control all survey work around the site. You should meet the following requirements:

- the stations should be referenced to Ordnance Survey National Grid co-ordinates
- the grid alignment should be accurate to within 1 metre and levels referenced to ordnance datum (OD)
- the horizontal accuracy should be not be less than 1 metre in 20 000 metres
- the level values of the stations should be accurate to within 0.005 metres
- a schedule of descriptions, co-ordinates and level values of all control stations, together with details of benchmarks used, should be submitted in writing to us.

8 You should undertake topographical surveys in accordance with your permit. The plan produced by the topographical survey should:

- be of an appropriate scale adequate to show the surveyed features of the landfill.
- be of a scale of at least 1:1250
- include 1 metre contours
- include the landform or an indication of the landform immediately adjacent to the landfill
- include all roads, structures, boundaries, monitoring points, extraction points and all other relevant site features in the permitted installation

Monitoring

. Recommendations for monitoring
• include the positions of ground features to within 1 metre • where there are significant landform changes since the previous survey, include spot levels to 0.01m at intervals of no greater than 50 metres in open areas of even gradient and spot levels to 0.01m at intervals of less than 50m when indicating embankments, stockpiles and other such features. You should ensure that there is an accurate record of the locations of engineering structures and their level referenced to OD.

Additional considerations for landfill of hazardous waste

9 The Landfill Directive requires that monitoring should check the processes within the landfill proceed as desired. You should undertake routine monitoring of landfill leachate and gas at landfills for hazardous waste. However, given the lack of UK experience of this type of landfill, you should consider carefully other additional monitoring necessary to demonstrate you are meeting the objectives for stabilisation of the waste body.

Monitoring

Records

Recommendations for record keeping

1 The Landfill Directive requires you to keep a register of the quantities and characteristics of the wastes deposited at your site (Article 11). This record can provide you with valuable historical information and will be used for statistical purposes by Government and the European Community. This register should include:

- quantity of waste deposited. This requirement is already common practice at UK landfills and may be recorded either in tonnage or volume
- waste characteristics. This information can be extracted from the basic characterisation information associated with the waste being sent to landfill, such as its List of Wastes code, the SIC code and appearance of the waste
- waste origin. Where practical the source of the waste should be recorded. However, sometimes waste will be delivered to a landfill within a multi-collection vehicle (from numerous origins). In these circumstances the name of the waste collector in combination with a designation of 'multi-collection vehicle' would be sufficient
- the delivery date
- the identity of the producer, or in the case of the municipal waste, the collector.

The waste producer is the person best placed to provide information on waste characterisation. In the event that waste is accepted on site that does not meet the relevant waste acceptance criteria, details of the waste producer will assist in subsequent investigations. For municipal waste, we recognise the waste producers are householders and therefore it would be more appropriate to record information on the collector of the waste. This is also appropriate for multi-collection vehicles.

Where you believe the identification of a specific waste producer is commercially sensitive, you should record this within your register and include a simple justification.

Additional considerations for landfill of hazardous waste

2 The Landfill Directive requires the precise location of deposits of hazardous waste to be registered (Article 11). This is also a requirement of Regulation 47 of the Hazardous Waste Regulations 2005.
This is already common practice on existing landfills and typically these pre-existing arrangements remain acceptable. The underlying principle you should meet is that waste deposits should be located within a particular cell by reference to x, y, z co-ordinates. There are a variety of methods you can use to identify the specific location

Monitoring

Recommendations for record keeping
within a cell. One option is for you to 'grid' an individual landfill cell into a number of zones using a hand held global positioning system and assign individual deposits to a particular zone and a specific waste lift/depth. For hazardous waste monocells (for example asbestos) individual deposits need only be assigned to a specific landfill cell.

4

Annexes

Annex 1 Emission benchmarks

Annex 2 References

Annex 3 Glossary and abbreviations

Annex 1-Emission benchmarks

4. Annexes

Annex 1- Emission benchmarks

Emissions of landfill gas

For landfill gas emission benchmarks ,you should refer to the relevant technical guidance (See Section 3.3 and references 33 to 37). The technical guidance covers release concentrations or mass release rates achievable for key substances using the best combination of techniques. These benchmarks are **not** mandatory release limits and you should refer to the relevant technical guidance regarding their use.

You should always take care to convert benchmark and proposed releases to the same 'reference conditions' for comparison. The guidance on monitoring landfill gas engine emissions and guidance on monitoring enclosed landfill gas flares (references 36 and 37) set out how to convert measured values to reference conditions.

Emissions to water

You should refer to 'Guidance on the treatment of hazardous and non-hazardous landfill leachate' (reference 45) for guidance on the management of effluent from a leachate treatment plant.

Releases to water may include emissions from leachate treatment plants, emissions to groundwater and surface water discharges or by tankering off-site. We follow our guidance H1 (reference 7) when deciding which limits to specify in a permit.

For groundwater, you should refer to guidance on hydrogeological risk assessment and the setting of trigger levels (reference 43).

Standards and obligations

There are also national and international standards and obligations that must either be safeguarded through the permit or, at least, taken into account in setting permit conditions, for example for any EC-based environmental quality standards (EQS).

Annex 1-Emission benchmarks

For EC-based EQSs you should refer to the Government Guidance on Part A installations which explains how these should be taken into account and contains an annex listing the relevant standards (reference 4).

Units for benchmarks and setting limits in permits

Releases can be expressed in terms of:

- 'concentration' (for example mg/l or mg/m^3), which is a useful day-to-day measure of the effectiveness of any abatement plant and is usually measurable and enforceable. The total flow must be measured/controlled as well
- 'specific mass release' (for example, kg/product or input or other appropriate parameter), which is a measure of the overall environmental performance of the plant (including the abatement plant) compared with similar plants elsewhere
- 'absolute mass release' (for example, kg/hr, t/yr), which relates directly to environmental impact.

When trying to reduce the environmental impact of your installation, you should consider its performance against all relevant benchmarks and assess where you can improve.

When we set limits in permits, the most appropriate measure will depend on the purpose of the limit. It may also be appropriate to use a substance as a surrogate for others, for example for groundwater protection. You may monitor these on a regular basis, supported by less frequent check-analyses of a wider range of substances.

For surface water, UK benchmarks or limits are most frequently 95 percentile concentrations or absolute concentrations, (with flow limited on a daily average or maximum basis).

Annex 2 References

Annex 2- References

Legislation

1	The Environmental Permitting (England and Wales) Regulations 2007 SI 3538. The Stationery Office, London.

Government Guidance

2	DEPARTMENT FOR ENVIRONMENT, FOOD & RURAL AFFAIRS: Environmental Permitting: Environmental Permitting Core Guidance, March 2008
3	DEPARTMENT FOR ENVIRONMENT, FOOD & RURAL AFFAIRS: Environmental Permitting: Environmental Permitting Guidance, The Landfill Directive, March 2008
4	DEPARTMENT FOR ENVIRONMENT, FOOD & RURAL AFFAIRS: Environmental Permitting: Environmental Permitting Guidance, Part A installations, March 2008

Environment Agency Regulatory Guidance

5	ENVIRONMENT AGENCY (2008) Environmental Permitting Regulatory Guidance Series No. LFD1. Understanding the Landfill Directive for Environmental Permitting.

Environment Agency Technical Guidance

Generic guidance

6	ENVIRONMENT AGENCY (2008) Environmental permitting regulations, standards and measures, getting the basics right - how to comply with your environmental permit, Environment Agency, Bristol
7	ENVIRONMENT AGENCY (2008) H1 Environmental Risk assessment: Part 1, Simple assessment of environmental risk for accidents, odour, noise and fugitive emissions. Part 2, Assessment of point source releases and cost-benefit analysis. Environment Agency, Bristol.
8	ENVIRONMENT AGENCY (2008) H3 Guidance for Noise. Environment Agency, Bristol.

Annex 2-References

9	ENVIRONMENT AGENCY (2008) H4 Guidance Note for Odour. Environment Agency, Bristol.
10	ENVIRONMENT AGENCY (2003) H5 Guidance on the Protection of Land: Application Site Report and Site Protection and Monitoring Programme. Environment Agency, Bristol.
11	ENVIRONMENT AGENCY (2004) M17: Monitoring of Particulate Matter in Ambient Air around Waste Facilities. Environment Agency, Bristol.

Guidance on waste acceptance and treatment

12	ENVIRONMENT AGENCY (2005) Guidance for Wastes Destined for Disposal in Landfills. Environment Agency, Bristol.
13	ENVIRONMENT AGENCY (2005) Guidance on sampling and testing to meet landfill waste acceptance procedures. Environment Agency, Bristol.
14	ENVIRONMENT AGENCY (2004) EPR 5.06: Guidance for the recovery and disposal of hazardous and non –hazardous waste. Environment Agency, Bristol.
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Water monitoring guidance

16	ENVIRONMENT AGENCY (2003) Guidance on the Monitoring of Landfill Leachate, Groundwater and Surface Water. Environment Agency, Bristol.

Annex 2-References

Landfill engineering guidance

17	ENVIRONMENT AGENCY (2001) Our approach to landfill engineering + ENVIRONMENT AGENCY (2009) How we assess engineering designs for landfill sites.
18	ENVIRONMENT AGENCY (2001) Guidance for inspecting the construction of landfill liners. Environment Agency, Warrington. ENVIRONMENT AGENCY 2009.
19	ENVIRONMENT AGENCY (2009) Using geomembranes in landfill.
20	ENVIRONMENT AGENCY (2009) Geophysical testing of geomembranes used in landfill.
21	ENVIRONMENT AGENCY (2009) Cylinder testing geomembranes and their protective materials
22	ENVIRONMENT AGENCY (2009) Using non woven protector geotextiles in landfill engineering.
23	ENVIRONMENT AGENCY (2009) Using geosythetic clay liners in landfill engineering.
24	ENVIRONMENT AGENCY (2009) Using bentonite enriched soils in landfill engineering
25	ENVIRONMENT AGENCY (2009) Earthworks on landfill sites - designing, constructing, and quality assuring.
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Annex 3 Glossary and abbreviations

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AFTERCARE	i) The steps necessary to bring the land to the required standard for the planned afteruse. ii) The period after closure prior to the acceptance of surrender during which maintenance and monitoring work is needed to ensure the restored landfill does not cause pollution of the environment, harm to human health or adverse effects on local amenities.
ATTENUATION	A decrease in concentration caused by any of a variety of mechanisms, individually or in combination, including, dilution, adsorption, precipitation, ion-exchange, biodegradation, oxidation, reduction.
BUND	A small bank of soil or other inert material used to define limits of cells or phases or roadways. Not a structural embankment which may be required to retain waste or liquid, but may be a permanent part of a landfill base, incorporating a liner.
CELL	A portion of the landfill surrounding a topographic low point encompassing all points from which it would collect free draining liquid. An individual cell would normally be expected to have a discrete basal leachate collection and extraction system and be separated from other cells by an engineered bund or sidewall lining system.
CLOSED	The point at which waste ceases to be accepted for disposal at a landfill
CLOSURE	A distinct stage in the regulatory 'life-cycle' of a landfill, subject to formal legal requirements described in Section 2.2. Closure is a process that occurs after the site is closed, but before it is definitely closed and can enter the aftercare phase.
CONSTRUCTION QUALITY ASSURANCE (CQA)	This is applicable specifically to construction activities and is an essential tool for the assurance of quality in landfill development. CQA is required to ensure that the objective of producing a high quality, practically flaw free structure is achieved.

Annex 3-Glosssary and abbreviations

DIRECT DISCHARGE	As defined in by the Groundwater Regulations 1998 – the introduction into groundwater of any substance in List I or II without percolation through the ground or subsoil
GROUNDWATER	As defined by the Groundwater Regulations 1998 – all water which is below the surface of the ground in the saturation zone and in direct contact with the ground or subsoil. Note: this differs from 'ground waters' as Controlled Waters (see definition).
INDIRECT DISCHARGE	Regulation 1(3) of the Groundwater Regulations 1998 – the introduction into groundwater of any substance in List I of II after percolation through the ground or subsoil.
LANDFILL	A landfill is a waste disposal site for deposit of the waste onto or into land and is defined by the Landfill Directive, article 2.
LANDFORM	The profile of the completed surface of a landfill.
LIST I AND LIST II SUBSTANCES	*Schedule to the Groundwater Regulations 1998*. Repeated from the Groundwater Directive and **not** necessarily the same as the List I and II substances noted in the Dangerous Substances Directive.
POLLUTION	*(a) As defined by the EP Regulations 2007:* emissions as a result of human activity that may be harmful to human health or the quality of the environment, cause offence to any human senses, result in damage to material property or impair or interfere with amenities and other legitimate uses of the environment. *(b) As defined by the Groundwater Regulations 1998:* the discharge by man, directly or indirectly, of substances or energy into groundwater, the results of which are such as to endanger human health or water supplies, harm living resources and the aquatic ecosystem or interfere with other legitimate uses of water,

Annex 3-Glosssary and abbreviations

POLLUTANT	Defined by the EP Regulations 2007 as any substance, vibration, heat or noise released as a result of such an emission that may have such an effect referring to (a) above.
SETTLEMENT	The amount by which a landfill surface sinks below its original level due to compaction by its own weight, and degradation of the waste. For example, a tipped waste thickness of 40 m settling by 8 m would have undergone 20% settlement. (This example is for finished surface levels only and does not consider the age or rate of degradation and settlement).
STABILISATION	As applied to landfill, this term includes the degradation of organic matter to stable products, and the settlement of the fill to its rest level. The process can take many years to complete. The term also refers to the use of plants and/or geotextiles to prevent soil erosion from the surface of a landfill or spoil heap.
SURCHARGE	To fill a landfill above final contours to allow for subsequent settlement. For example, if 20% settlement is predicted and a 100 m finished waste thickness is required, then a surcharge of 25 m of waste is required, in other words, the total placed waste thickness would be 125 m.

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