www.environment-agency.gov.uk

Assessing the Groundwater Pollution Potential of Cemetery Developments

Science Group: Air, Land & Water

ENVIRONMENT AGENCY

www.environment-agency.gov.uk

The Environment Agency is the leading public body protecting and improving the environment in England and Wales.

It's our job to make sure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

Our work includes tackling flooding and pollution incidents, reducing industry's impacts on the environment, cleaning up rivers, coastal waters and contaminated land, and improving wildlife habitats.

Published by:

Environment Agency
Waterside Drive, Aztec West
Almondsbury, Bristol BS32 4UD
Tel: 01454 624400 Fax: 01454 624409

Product Code SCHO0404BGLA-E-P

This report is printed on Cyclus Print, a 100% recycled stock, which is 100% post consumer waste and is totally chlorine free. Water used is treated and in most cases returned to source in better condition than removed.

Image reproduced courtesy of Tamany Baker

Scope

This booklet aims to inform operators and local authority planners on how to assess the potential pollution risks to groundwater from new and existing cemetery developments.

Introduction

The burial of corpses in cemeteries, and their subsequent degradation, may potentially cause pollution of groundwater. Local authorities have a responsibility for control of new cemeteries through the planning process. The Environment Agency (the Agency) has new powers under the Groundwater Regulations 1998 to take action where groundwater pollution occurs, or is likely to occur. Clearly, measures to prevent pollution must be appropriately considered, given the sensitivity and nature of cemeteries.

To address these problems, and so that regulatory decision making can be based on sound scientific knowledge, a study of existing information was commissioned by the Agency to:

- review published studies relating to the potential environmental threat posed by cemeteries;
- identify and quantify the risks of pollution, where possible, by reference to published cases;
- review our current approaches to assessing proposals for extending cemeteries or developing new ones;
- provide guidance on assessing the relative importance of the factors that require consideration in terms of the potential impact of a cemetery on groundwater.

The output of this study, R&D Technical Report P223[1], forms the basis of this summary guidance document, which focuses on a risk-assessment framework for the issues raised.

Legal framework

The earliest legislation governing the location, development and operation of cemeteries is the Cemeteries Clauses Act of 1847. The Local Planning Authority is the principal body controlling such developments, under the Town and Country Planning Act 1990 and the Planning and Compensation Act 1991. The only means of control is through conditions set in the Decision Notice, an obligation (agreement or undertaking) under Section 106 of the 1990 Act, or ultimately by refusal of planning permission.

As a statutory consultee, the Agency's views must be considered unless the Local Planning Authority can justify why its requirements should not be included. Planning permission is not required, however, for:

- private non-commercial burial;
- the burial of a limited number of individuals on their own land;
- the re-ordering of graves within Anglican churchyards.

All of these are still subject to any restrictive covenants affecting the use of the land, and the burials must not create other nuisances such as smell or pollution.

The Agency has a duty to protect the quality of surface and groundwater resources under the Water Resources Act 1991 (see **Table 1**). However, this only gives us limited powers to control such developments directly. ***The Policy and Practice for the Protection of Groundwater*** [2] (PPPG) was published to influence others and to ensure groundwater pollution is prevented. It provides a risk-based framework for evaluating proposals and seeks to influence planning decisions about the location of any new development that may have an impact on groundwater or any other specific sources of water supply.

Environment Agency tools

Groundwater vulnerability maps[i] and groundwater Source Protection Zones[ii] (SPZ) are tools for highlighting areas where there are likely to be particular risks posed to groundwater.

Groundwater vulnerability maps show the dangers from pollution to groundwater. Aquifers are defined according to their relative importance in yielding water supply into major, minor and non-aquifers. Reference is also made to the vulnerability of the soils in terms of their leachability and attenuation of contamination.

---

i Groundwater vulnerability maps are available from The Stationery Office. Tel: 020 7873 8732, quoting ref 54.

ii Available on the Agency's website at: **www.environment-agency.gov.uk**, in 'What's in your back yard'.

Origin	Legislation	Agency role
Europe	EC Groundwater Directive (80/68/EEC).	Competent authority.
UK	Water Resources Act 1991 (s.92).	Powers to control discharges to controlled waters.
	Water Resources Act 1991 (s.161).	Powers under regulations to require pollution prevention measures to be taken.
	Water Resources Act 1991 (s.93).	Provision for statutory water protection zones.
	Waste Management Licensing Regulations 1994 (from s.33 of the Environmental Protection Act 1990).	Powers to prevent pollution by substances listed in EC Groundwater Directive.
	Groundwater Regulations 1998 (brought into force between 02/12/98 and 01/04/99).	Powers to prevent or control activities that may result in the discharge of specified pollutants to groundwater.

Table 1 Groundwater protection legislation directly implemented by the Agency

SPZs are delineated around groundwater abstractions used for public consumption and are defined by travel-time of biological/other contaminants in groundwater to the abstraction. Three zones are defined:

- **Zone I** – 50-day travel-time or a minimum of 50m from the source to the abstraction point;
- **Zone II** – 400-day travel-time or 25 per cent of source catchment area;
- **Zone III** – total catchment area for the abstraction.

Preparation and methods of burial

Current UK practices for the preparation of bodies for burial and methods of burial are summarised below:

- embalming – half of all burials involve some embalming with formalin solution. The use of toxic metals or alkaloids has been banned since 1951;
- coffins – mainly constructed of chipboard or MDF with a paper veneer;

- for a single burial, the base of the coffin must be 1.8m below ground level;
- commercial burial of pets is in accordance with the voluntary code of conduct set out by the Association of Private Pet Cemeteries and Crematoria;
- at green burial sites, the corpse is enclosed by a biodegradable coffin or shroud at a depth of at least 1.3m with grass or shrub cover over the grave.

Special cases

Green Burials

Between 50 and 100 green burials occur annually in Great Britain. They are located in areas such as woodlands, nature reserves and gardens. Case law confirms that in such cases no planning permission is required for "a limited number of unmarked and unfenced graves."

However, the Institution of Burial and Cremation Authorities recommends that people contemplating private burial should consult the Agency and their local council's Environmental Health Department about possible pollution of the environment and public nuisance. There is no law against burial in one's own garden, but a burial authorisation form must be completed beforehand giving details of the date and location of burial.

The burial must also be recorded in a land burial register and a detailed plan identifying where the body is buried should be kept with the deeds of the property.

It is recommended that a suitable grave should:

- be located more than 10m from standing/running water and more than 50m from a well, borehole or spring supplying potable water for human consumption;
- have no standing water at the bottom when it is first dug
- not be dug in very sandy soil;
- be deep enough to prevent foraging animals from disturbing the body.

Further information can be obtained from ***The New Natural Death Handbook***[3].

Pet cemeteries

Most domestic animals are buried on the owner's premises or landfilled by veterinary practices. However, the use of private pet cemeteries and crematoria is on the increase. The Association of Private Pet Cemeteries and Crematoria has produced self-regulatory guidance[4].

This recommends burial of unembalmed remains in biodegradable cardboard coffins at a depth of at least 0.9m, with grave plots avoiding watercourses, drains and wells. Up to 30 per cent of pet burials may be in small chipboard coffins. The density of canine burials (the most common subject in pet cemeteries) is around 10,000 per hectare (about four times the normal human occupancy rate).

Human mass burials

When a large number of bodies require disposal, for instance after a major disaster, the remains are most likely to be cremated. However, in many cases temporary storage facilities are required. In all cases, a 'wet' area must be designated to contain bodily fluids/wastes and chemicals. If drain discharges from this area are unsuitable (for example, a soakaway), then all drains must be sealed and liquids must be collected and disposed of safely by a specialist contractor.

Composition of corpses and potential pollution releases

The composition and elemental components of a typical human body are indicated in **Table 2** .

The pollutants derived from human corpses are found as dissolved and gaseous organic compounds and dissolved nitrogenous forms (particularly ammoniacal nitrogen). There is also the potential, depending upon the background environment, for increased pH resulting from the high proportion of calcium.

Composition	(% weight)[5]
Water	64
Protein	20
Carbohydrate	1
Mineral salts	5
Fat	10
Elemental component	**mass (g)**
Oxygen	43000
Carbon	16000
Hydrogen	7000
Nitrogen	1800
Calcium	1100
Phosphorus	500
Sulfur	140
Potassium	140
Sodium	100
Chlorine	95
Magnesium	19
Iron	4.2
Copper	0.07
Lead	0.12
Cadmium	0.05
Nickel	0.01
Uranium	0.00009
Total body mass	70000

Table 2 Composition and elemental components of a typical human body

Factors affecting rate of release

The proportions of degraded matter in a human corpse are shown in **Table 3**.

Category	%
Readily degradable	60
Moderately degradable	15
Slowly degradable	20*
Inert (non-degradable)	5*

* Assumes that mineral salts (ashes) form final stable residue. The slowly degradable component of bones may be considered inert for practical purposes.

Table 3 Proportions of readily and slowly degraded matter in a coffined human corpse

The primary process governing the production, release and potential migration of pollutants from a buried corpse is microbial decay. The rate of decay depends on the extent of microbial growth and activity. This is influenced by the:

- availability of nutrients (carbon, nitrogen, phosphorus, sulphur) and moisture – the high water content of a corpse and the favourable carbon:nitrogen: phosphorus ratio in vertebrate bodies (about 30:3:1) encourages rapid and complete degradation of the corpse;
- pH – neutral pH conditions are most favourable;
- climate – warm temperatures accelerate decomposition;
- soil lithology – well-drained soil will accelerate decomposition, whereas poorly drained soil (for example. peat) has the reverse effect.
- burial practice – depth of burial and coffin construction control the ease with which invertebrates/ vertebrates may gain access to the corpse and hasten its decay.

Pathogens may also be present, but these will die off naturally and rapidly reduce in concentration with increasing distance from the grave. Their survival is also governed by physical conditions (for example, temperature, moisture content, organic content, pH).

Potential contaminant release rates

A human corpse normally decays within 10 to 12 years. It is estimated that over half of the pollutant load leaches within the first year and halves year-on-year. Less than 0.1 per cent of the original loading may remain after 10 years (see **Table 4**).

The time taken to flush out contaminants from the burial is directly related to the effective rainfall and infiltration rate through the soil and grave. **Table 5** (overleaf) provides an estimate of the infiltration of water through a typical grave plot. Therefore, to estimate the possible

Year	TOC	NH_4	Ca	Mg	Na	K	P	SO_4	Cl	Fe
1	6.00	0.87	0.56	0.010	0.050	0.070	0.250	0.210	0.048	0.020
2	3.00	0.44	0.28	0.005	0.025	0.035	0.125	0.110	0.024	0.010
3	1.50	0.22	0.14	0.003	0.013	0.018	0.063	0.054	0.012	0.005
4	0.75	0.11	0.07	0.001	0.006	0.009	0.032	0.027	0.006	0.003
5	0.37	0.05	0.03	<0.001	0.003	0.004	0.016	0.012	0.003	0.001
6	0.19	0.03	0.02	<0.001	0.002	0.002	0.008	0.006	0.002	<0.001
7	0.10	0.01	0.01	<0.001	0.001	0.001	0.004	0.003	<0.001	<0.001
8	0.05	<0.01	<0.01	<0.001	<0.001	<0.001	0.002	0.001	<0.001	<0.001
9	0.02	<0.01	<0.01	<0.001	<0.001	<0.001	0.001	<0.001	<0.001	<0.001
10	0.01	<0.01	<0.01	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001

Table 4 Potential contaminant release (kg) from a single 70kg burial

average composition of effluent reaching the water table beneath the burial ground, the contaminant release is divided by the total annual infiltration. For instance, an embalmed body contains 180g of formaldehyde in 9 litres of embalming fluid. Assuming that about half of this is degraded rapidly in the decomposition process and with grass surface cover controlling the rainfall infiltration (see **Table 5**), the initial concentration in the effluent would be about 90mgl^{-1}. Four years later though this would have declined to about 5mgl^{-1} and ten years later would be only 0.1mgl^{-1}.

However, these estimates take no account of the natural degradation of formaldehyde in the ground, so the concentrations are likely to be lower.

The embalming of bodies is discouraged for green burials, so they are not considered to be a significant potential source of formaldehyde pollution.

Transport of microbes/pathogens

The transport of microbes/pathogens within the groundwater is affected by the characteristics of the organism (size, shape, activity) and the method of transport through the aquifer. Water extracted from shallow depth with a shorter travel-time since recharge has a higher pollution risk than an extraction drawing on water with a long residence time. Using short travel-times/pathways as a

Grave cover	Surface infiltration (1yr⁻¹)	Infiltration from grass surrounds (1yr⁻¹)	Total (1yr⁻¹)
Chippings	750	500	1,250
Grass	500	500	1,000
Green burial	250	760	1,010

Assumes:

1 a standard grave size of2.1 x 1.2m
2 mean annual rainfall of 650mm and typical evapotranspiration losses
3 1976 graves per hectare for conventional burials
4 1580 graves per hectare for "green" burials

Table 5 Estimation of water flux through a typical grave area

prime criteria, many spring systems and shallow wells are more vulnerable to microbial pollution problems than deep wells or boreholes.

Attenuation of contaminants from burial sites

Contaminants from a burial site may migrate into:

- the soil zone surrounding the burial;
- the unsaturated zone of the underlying aquifer;
- the saturated zone of the aquifer.

Figure 1 shows the natural attenuation processes that may take place in each zone to remove contaminants, including microbial/ pathogen contaminants.

Soils are complex in composition and are the site of intense biochemical reactions, so contaminants may change while passing through them. Air access is generally good (unless the soil is waterlogged), encouraging the rapid oxidation of pollutants. The main processes contributing to the attenuation of pollutants are filtration, sorption, biodegradation and chemical oxidation/reduction.

Below the soil, in the unsaturated zone, less chemical and biological activity takes place than in the overlying soils. Oxygen diffusion from the surface is low and anoxic conditions may develop. However, chemical and biochemical reactions may continue to attenuate pollutants. Filtration and sorption may continue to de-mobilise particulates and some dissolved pollutants.

The potential for the aquifer matrix to remove pathogenic organisms by filtration depends on the nature of the matrix. Where the major route for groundwater flow is through a porous intergranular matrix

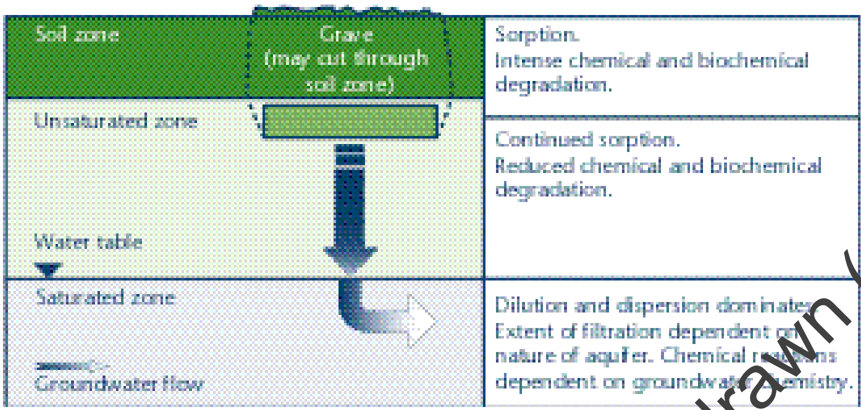

Figure1 | Natural attenuation processes in the sub-surface

(intergranular flow), such as sandstone aquifers, there is high filtration potential. Conversely, in aquifers where fractures provide the predominant flow route, such as chalk aquifers, the potential for filtration of microbes is limited.

Further details can be obtained from the booklet ***Microbiological Contaminants in Groundwater***[6] or the report on which it is based, R&D Technical Report P139 ***A Review of the Microbiological Contaminants in Groundwater***[7].

Assessment of risks from cemeteries

To assist in the decision-making process, a three-tiered approach to assessing the risks from cemeteries or potential cemetery sites is recommended. This is based on the report ***Guidelines for Environmental Risk Assessment and Management***[8] and the R&D Technical Report P223[1].

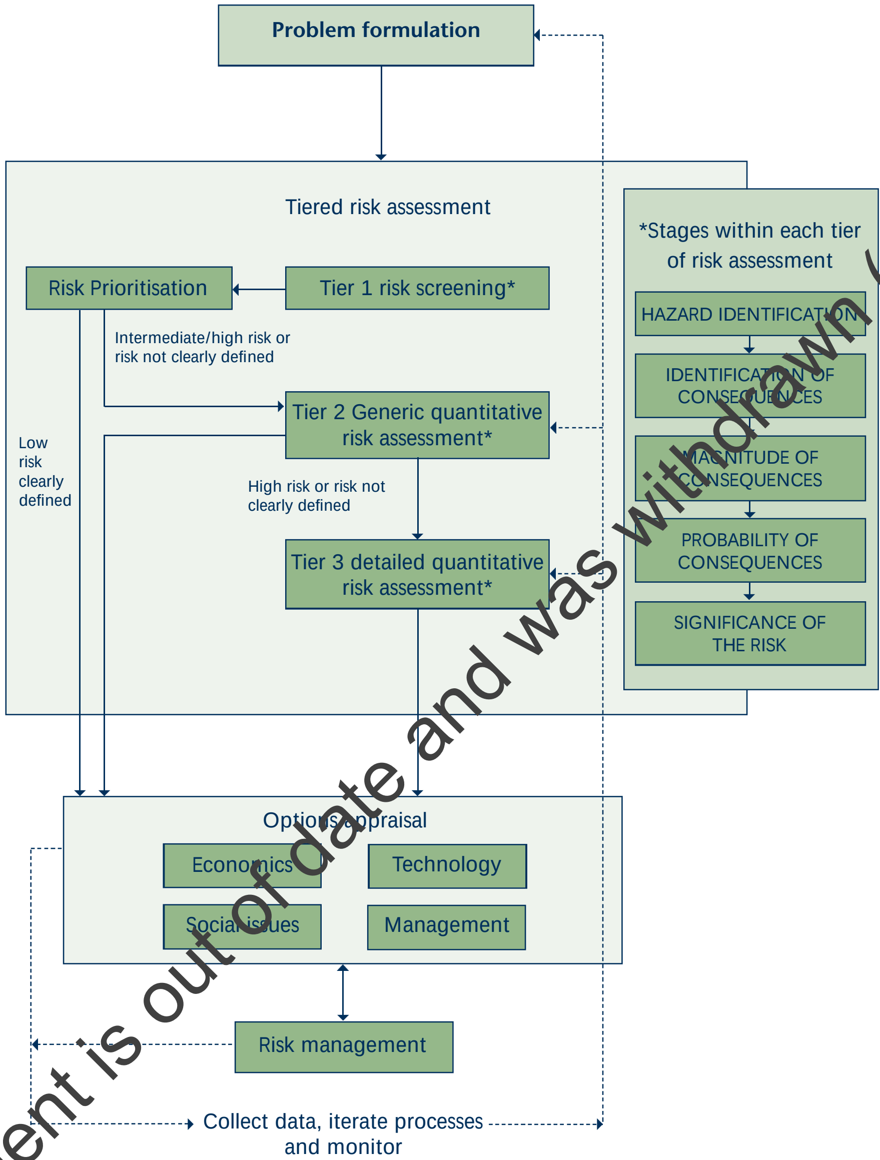

Figure2 Risk assessment framework [8]

Figure 2 shows the framework to follow for assessing the risks using a tiered approach. The level of effort and detail put into assessing each risk is in proportion to its priority and complexity in relation to understanding the likely impacts.

Problem formulation

Before undertaking a risk assessment, the objectives must be clearly defined. This will also determine the limits of the scope of the study (for example, geographical, chronological, and financial). The objectives should cover why the risk assessment is being undertaken and include consideration of any social or political issues.

Common stages of the risk assessment

Each tier of the risk assessment involves the same series of stages, namely:

- hazard identification;
- identification of consequences;
- magnitude of consequences;
- probability of consequences;
- significance of risk.

Tier 1: Risk screening

This is essentially a desk-study stage, where a preliminary site assessment should take place, using all readily available information. The research should include published maps (topographical, geological, hydrogeological) and abstraction licence records. However, the most important data sources in this desk study are the groundwater vulnerability maps, the SPZ maps and information on springs, private drinking water supply boreholes and groundwater-fed surface waters.

An assessment of the hazard(s) should be made, potential pathways and receptors should be identified and reviewed, and a qualitative assessment undertaken of the significance of the risks posed for example, high, intermediate or low.

The consequences of the hazards can be modified by social factors. For example, the risk of odour at a green burial site in a rural location may be seen as acceptable compared to a similar odour in a metropolitan cemetery.

The vulnerability of potential receptors must be determined. In the case of burial sites, the most important receptor is groundwater (including boreholes, wells and springs used for human consumption). Other receptors, including surface water, are not considered further in this document. The principal factors controlling groundwater vulnerability are listed below:

- soil nature and type, including structure, leaching potential and soil vulnerability based on physical properties affecting the downward migration of water and the ability of the soil to attenuate;
- presence and nature of drift, including type and thickness;
- depth to the water table, as unsaturated zone can attenuate contamination by physical, biological and chemical processes;
- groundwater flow mechanism (intergranular or fissured);
- groundwater vulnerability and aquifer type (major, minor, non aquifer);
- abstractions;
- groundwater SPZs;
- proximity of watercourses, springs and drains.

In a Tier 1 assessment, a qualitative approach can be used whereby each item listed can be ranked using a scoring system to prioritise those that are of most concern. The overall vulnerability can then be assessed as low, medium or high. An example is given in the R&D report[1].

Once the vulnerability of the site is known, it is necessary to consider what level of risk assessment is appropriate. This depends on the scale of the development in terms of estimated burials per year and whether the bodies are to be human or animal. If the overall risk is low, the proposals may be accepted by the Agency without further detailed assessment. However, there will probably be a request for pragmatic controls to comply with best practice and these will be implemented by planning conditions.

Such controls include:

- 250m minimum distance from potable groundwater supply source;
- 30m minimum distance from watercourse or spring;
- 10m minimum distance from field drains;
- no burials into standing water.

Any proposal located within a Source Protection Zone I (Inner Zone) is likely to be opposed by the Agency as the risk to groundwater is considered to be high. A minimum of a Tier 3 assessment (detailed quantitative risk assessment) would be required.

Proposals within a Zone II (Outer Zone) are likely to have restrictions imposed on them. Further Tier 2 assessment (generic quantitative risk assessment) or Tier 3 assessment will probably be required as the risk is likely to be intermediate or high.

Any proposal located within a Zone III (Total Catchment) would generally be considered of intermediate risk unless the site's intrinsic vulnerability was higher.

Borderline cases should be dealt with in the intermediate category unless clarification can be gained that would allow the site to be classified as low risk. For example, a small extension to a low-use graveyard of a small parish church near a watercourse may be acceptable if there are no records of adverse effects from previous burials.

After the Tier 1 risk assessment has been carried out, the risks can be prioritised and considered further in the options appraisal. Here, the options for risk management are identified and evaluated. Options may include:

- reducing the hazard through new technology, procedures or investment;
- mitigating effects through improved environmental management techniques.

Due to the sensitivity of the issues associated with burial sites and the complex, site-specific nature of the hydrogeological assessments, the application of qualitative screening is limited. A Tier 1 assessment is likely to be of use only for an existing site, with no prior history of environmental problems, where a minor change is proposed. In all other cases, at least a Tier 2 assessment should be carried out.

Tier 2: Preliminary quantitative risk assessment with detailed desk study and preliminary site investigation

A Tier 2 assessment should be carried out for sites designated as intermediate-risk sites in Tier 1, or where the risks are not clearly defined. Such sites should be subject to a more detailed desk study, some level of investigation and monitoring to identify the hazards. Applicants will also have to provide additional data, which may include an assessment of the potential contaminant loading and likely attenuation within the transport pathways through simple calculations. **Table 6** lists the minimum information requirements for a Tier 2 assessment.

For any proposal to be acceptable, the assessment should show that no impact on groundwater would occur or, at worst, that the impact would not amount to pollution as defined in the Groundwater Directive (that is, no impact from List I and ideally

Information required	Tier 2 Assessment	Tier 3 Assessment (additional works or variations from intermediate risk requirements)
Site description	Local survey to supplement data on appropriate Ordinance maps Survey (e.g. Superplans).	Location, area and topography based on accurate site survey. Any landscaping included in the proposal is to be identified.
Number, type and sequence of burials	Projections on which annual numbers are based should be available, along with supporting data and explanation.	Projections on which annual numbers are based should be available, along with supporting data and explanation. Plan of the proposed sequence of burial area usage with indication of expected progression over time.
Meteorological factors	Long-term average Met. Office data on local rainfall and MORECS soil moisture data.	Analysis of available Met. Office data to derive monthly mean, maximum and minimum effective rainfall and soil moisture data for bare soil, short-rooted vegetation and deep-rooted vegetation.
Soil/subsoil characteristics	Soil Survey maps. Possible site investigation and percolation tests.	Site survey with augering and trial pits.
Superficial geology/ hydrogeology	Geological and hydrogeological maps and memoirs (British Geological Survey). Limited site investigation (trial pits and drilling) may be necessary if insufficient data is available. Groundwater Vulnerability data and location of any nearby source protection zones.	Lithology, mineralogy and grain size distribution to be determined by drilling investigation. Presence/ absence of shallow groundwater, fluctuations in water table (seasonal or otherwise) to be monitored for not less than one year of monthly measurements.
Solid geology/ hydrogeology	As above, with an assessment of the aquifer characteristics from available published data.	For non-aquifer, proof of lithology by direct investigation (not less than 10m) required to exclude the likelihood of any local higher permeability horizons.

Table 6 Potential information requirements for Tier 2 and Tier 3 risk assessments

Solid geology/ hydrogeology	If aquifer is present, a minimum of three investigation boreholes are required. One on the up-gradient side of the site boundary and two close to the down-gradient boundary.	If aquifer is present, a minimum of three investigation boreholes are required. One on the up-gradient site boundary and two close to the down-gradient boundary. Holes to be at least10m below the minimum groundwater level. Geological data to be obtained and hydrogeological investigations to be undertaken (e.g. estimation of permeability based on falling head test, bailing test, tracer tests).
Groundwater quality	Background quality data required; quarterly sampling and analysis for at least one year to detect any seasonal variations. See 'Monitoring' section for recommended analytical suites.	Monthly sampling at least one year from local and on site boreholes (see above). See 'Monitoring' for analytical suite.
Surface water quality	As above, quarterly sampling for at least one year. See 'Monitoring' section.	Monthly sampling for at least one year. See 'Monitoring' section.
Proximity to water source/ resource	Environment Agency records of licensed abstraction sources. Local Environmental Health Department records of private domestic sources (these are not comprehensive). Search should include surface and groundwater sources.	Environment Agency records of licensed abstraction sources. Local Environmental Health Department records of private domestic sources (these are not comprehensive). Search to include groundwater and surface water sources for potable and non-potable usage. Investigation to include water features survey of an area around the site dependent on the size of site, proposed usage rate and nature of the aquifer.
Proximity to housing or other developments	Check local/regional/national planning authority for potential residential, educational, commercial/ industrial developments, roads, rail and mineral extractions.	As for intermediate risk sites.
Data assessment protocols	Simple pollutant flux and water balance calculations.	Possible use of stochastic models to assess range and probability of risk.

no impact from List II substances). If the proposal is deemed acceptable, conditions should be requested that ensure pollution does not take place. Otherwise an objection will be raised by the Agency or a more detailed site investigation will be requested from the applicant.

Tier 3: Detailed quantitative risk assessment

If the risk is deemed to be high or is still not clearly defined from the Tier 2 assessment, a Tier 3 assessment is required. Sites falling into this category are likely to be large in terms of both input rate and total area. A burial rate of 1,000 per year would be typical of a town with 150,000 to 250,000 inhabitants and would equate to about 70 tonnes per year.

In cases where there seems to be a high risk of pollution to groundwater, a more detailed site investigation, risk assessment and monitoring is required. The use of groundwater modelling techniques or other stochastic models will probably be necessary. **Table 6** lists the information requirements for a Tier 3 assessment.

Direct investigation of the properties of the soils and rock to 1m below grave depth would be expected. Hydrogeological investigations should be based on site-specific data. Where this is not available, investigations should be conducted by the applicant with our agreement.

For a proposal to be acceptable, the assessment should show that no List I and, ideally, no List II substances should impact upon the groundwater. Microbiological contaminants must not endanger water resources or supplies.

When a proposal is accepted, conditions should be applied to ensure pollution does not occur. If this is not achievable, an objection will be raised.

Other factors for consideration

Sites with a shallow water table may require dewatering to take place when new graves are dug. The measures for the disposal of such potentially contaminated water should be considered.

Green burial sites usually exhibit accelerated decay rates due to the relatively shallow depth of burial, the biodegradable nature of the coffins or shrouds and the lack of embalming fluids. The infiltration rate may be lower on such sites due to evapotranspiration by trees and shrubs. Decay will principally be aerobic, producing carbon dioxide, water, nitrate and sulphate, which are generally less polluting than those from anaerobic decay.

Pet cemeteries may have a lower or equivalent pollution potential than human burial grounds. Body mass is less, but burial density is greater than a typical human cemetery. Depth of burial (1m standard), the use of readily biodegradable coffins and the lack of embalming encourage rapid decay processes. Pet cemeteries may require a waste management licence under the Environmental Protection Act (1990). Appropriate operational controls and monitoring can be maintained by applying licence conditions.

Monitoring

In the absence of specific guidance for monitoring and sampling around burial sites, the Agency recommends that requisite monitoring and sampling should be carried out in accordance with current best practice for monitoring of groundwater around landfill sites. This is set out in the report Guidance on Monitoring of Landfill Leachate, Groundwater and Surface Water 9. It suggests a risk-based approach for designing a monitoring programme. Monitoring should be carried out to:

- define the baseline water quality and physical conditions in surrounding groundwater and surface water before development;
- identify all vulnerable receptors and help identify potential pathways;
- provide an early warning of adverse environmental impacts.

The minimum requirements for groundwater monitoring are given in **Table 7** overleaf.

If values of the indicator determinands consistently depart from the background levels, the recommended suite of determinands should be increased to those listed for establishing baseline conditions. Also, if evidence of contamination is indicated by the inorganic determinands, sampling for bacterial indicators (especially ***Psuedomaona aeroginosa,*** faecal streptococci, or Clostridium spp.) is recommended on a quarterly basis.

If monitoring demonstrates that groundwater pollution is taking place, burials at the site should be halted while further investigations are undertaken to determine the reason for deterioration.

More information

Further National Centre and Science Group reports and other booklets in this series are available from the Agency website: **http://www.environment-agency.gov.uk.**

	Low-site risk	Intermediate-risk site	High-risk site
Minimum borehole monitoring period	None	12 months before site development and 12 months after site development.	12 months before site development and 12 months after site development.
Minimum number of boreholes for site monitoring	None	One hole on the up-gradient boundary of the site and two boreholes on the down-gradient boundary (spaced no more than 100m apart).	One hole on the up-gradient boundary of the site and two boreholes on the down-gradient boundary (spaced no more than 100m apart).
Off-site monitoring	None	None	Monitoring between the site and receptors at risk down-gradient. One hole for each receptor and/or pathway located on the pathways connecting site and receptor.
Number and frequency of monitoring points for surface waters, if affected	None	One point upstream and one downstream. To be monitored on a monthly basis.	One point upstream and one downstream. To be monitored on a monthly basis.
Frequency of monitoring and suite* of determinands for monitoring of baseline conditions prior to development	None	Quarterly – water level, pH, temperature, electrical conductivity, dissolved oxygen, NH_4-N, Cl. Six monthly – SO_4, TON (sum of NO_3 + NO_2), TOC, BOD, COD, alkalinity, Na, K, Ca, Mg, Fe, Mn, Cd, Cr, Cu, Ni, Pb, Zn, P.	Monthly – water level, pH, temperature, electrical conductivity, dissolved oxygen, NH_4, N, Cl. Quarterly – SO_4, TON (sum of NO_3 + NO_2), TOC, BOD, COD, alkalinity, Na, K, Ca, Mg, Fe, Mn, Cd, Cr, Cu, Ni, Pb, Zn, P.
Frequency of monitoring** and suite of determinands for long-term monitoring once the site is in use (indicators of contamination)	None	Six monthly – water level, pH, temperature, electrical conductivity, dissolved oxygen, TON (sum of NO_3 + NO_2), TOC, BOD, COD, ammoniacal nitrogen, SO_4, Cl, Na, K, Ca, Mg, Fe, P.	Six monthly – water level, pH, temperature, electrical conductivity, dissolved oxygen, TON (sum of NO_3 + NO_2), TOC, BOD, COD, ammoniacal nitrogen, SO_4, Cl, Na, K, Ca, Mg, Fe, P.

* Other determinands that may need to be considered on a site-specific basis are organics, List I & II substances and Red List substances.

** May be reduced to annual monitoring if stable conditions are proven.

Table 7 Recommended minimum requirements for groundwater monitoring

References

1 Young, C.P., Blackmore, K.M., Reynolds, P.J. and Leavens, A., (1999). ***Pollution Potential of Cemeteries***, R & D Technical Report P223, 61pp. Environment Agency. ISBN 1857050215.

2 Environment Agency, (1998). ***Policy and Practice for the Protection of Groundwater*** (2nd Edition), 57pp. HMSO. ISBN 0113101457.

3 Albery, N. and Wienrich S., (Eds.), (2000). ***The New Natural Death Handbook***, The Natural Death Centre, 382pp. (3rd edition), Rider. ISBN 0712605762 (www.naturaldeath.org.uk)

4 Ricketts, Nick, (1998). Association of Private Pet Cemeteries and Crematoria. Pers. Telecon. 2 June 1998.

5 Van Haaren, F.W.J., (1951). Cemeteries as Sources of Groundwater Contamination Water, 35(16), 167-172.

6 Environment Agency, (1999). ***Microbiological Contaminants in Groundwater***. National Groundwater and Contaminated Land Centre, Solihull. Booklet.

7 West, J. M., Pedley, S., Barker, S.J., Barrott, L., Morris, B., Storey, A., Ward, R. S. and Barrett, M., (1999). ***A Review of the Microbiological Contaminants in Groundwater***. R & D Technical Report P139. Environment Agency.

8 DETR, Environment Agency & Institute for Environment and Health (2000). ***Guidelines for Environmental Risk Assessment and Management***, 89pp. HMSO. ISBN 0117535516.

9 Dumble, P. & Ruxton, C., (2000). ***Guidance on Monitoring of Landfill Leachate, Groundwater and Surface Water***. Environment Agency, R&D Report, ISBN 185 705 637 X.

CONTACTS:

ENVIRONMENT AGENCY HEAD OFFICE

Rio House, Waterside Drive, Aztec West, Almondsbury, Bristol BS32 4UD.
Tel: 01454 624 400 Fax: 01454 624 409

www.environment-agency.gov.uk
www.environment-agency.wales.gov.uk

SCIENCE GROUP: AIR, LAND & WATER

Olton Court, 10 Warwick Road, Olton, Solihull B92 7HX.
Tel: 0121 708 4714 Fax: 0121 708 4637

ANGLIAN
Kingfisher House
Goldhay Way
Orton Goldhay
Peterborough PE2 5ZR
Tel: 01733 371 811
Fax: 01733 231 840

MIDLANDS
Sapphire East
550 Streetsbrook Road
Solihull B91 1QT
Tel: 0121 711 2324
Fax: 0121 711 5824

NORTH EAST
Rivers House
21 Park Square South
Leeds LS1 2QG
Tel: 0113 244 0191
Fax: 0113 246 1889

NORTH WEST
PO Box 12
Richard Fairclough House
Knutsford Road
Warrington WA4 1HG
Tel: 01925 653 999
Fax: 01925 415 961

SOUTHERN
Guildbourne House
Chatsworth Road
Worthing
West Sussex BN11 1LD
Tel: 01903 832 000
Fax: 01903 821 832

SOUTH WEST
Manley House
Kestrel Way
Exeter EX2 7LQ
Tel: 01392 444 000
Fax: 01392 444 238

THAMES
Kings Meadow House
Kings Meadow Road
Reading RG1 8DQ
Tel: 0118 953 5000
Fax: 0118 950 0388

WALES
Cambria House
29 Newport Road
Cardiff
CF24 0TP
Tel: 029 2077 0088
Fax: 029 2046 6404

ENVIRONMENT AGENCY
GENERAL ENQUIRY LINE
0845 933 3111

ENVIRONMENT AGENCY
F L O O D L I N E
0845 988 1188

ENVIRONMENT AGENCY
EMERGENCY HOTLINE
0800 80 70 60

ENVIRONMENT AGENCY

HO-AW-04/01-0k

www.environment-agency.gov.uk

We welcome feedback including comments about the content and presentation of this report.

If you are happy with our service please tell us. It helps us to identify good practice and rewards our staff. If you are unhappy with our service, please let us know how we can improve it.

For further copies of this report or other reports published by the Environment Agency, contact general enquiries on 0845 9333111 or email us on enquiries@environment-agency.gov.uk

Environment Agency