



Guidance for the Safe Development of Housing on Land Affected by Contamination

Appendices and Annexes

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Volume 2

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Appendix 1

Glossary

Acute	A condition or disease of rapid onset/severe symptoms/brief duration.
Anaerobic	In the absence of oxygen.
Asphyxiant	A vapour or gas which causes unconsciousness or death by suffocation (lack of oxygen).
Chronic	A condition or disease of long duration involving very slow changes, often of gradual onset.
Composite sampling	Where a composite sample is formed from the combination of several sub-samples collected at different locations within the sampling area.
Conceptual model	A representation of the characteristics of the site in diagrammatic or written form that shows the possible relationships between contaminants, pathways and receptors.
Contaminant	A substance that is in, on or under the land and that has the potential to cause harm or to cause pollution of controlled waters.
Contaminated land	Defined in s78A(2) of EPA 1990 as “any land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in, on or under the land, that (a) significant harm is being caused or there is a significant possibility of such harm being caused, or; (b) pollution of controlled waters is being, or is likely to be caused”.
Controlled waters	Defined by Water Resources Act 1991, Part III, section 104, which includes all groundwater, inland water, estuaries and coastal water to three nautical miles from the shore.
Data quality	The extent to which data about a site and its setting provide a complete, relevant, reliable and clear account of likely or true conditions.
Desk study	Interpretation of historical, archival and current information to establish where previous activities were located, and where areas or zones that contain distinct and different types of contamination may be expected to occur, and to understand the environmental setting of the site in terms of pathways and receptors.
Detailed quantitative risk assessment	Risk assessment carried out using detailed site-specific information to estimate risk or to develop site-specific assessment criteria.
Detailed site investigation	Main stage of intrusive site investigation, which involves the collection and analysis of soil, surface water, groundwater, soil gas and other media as a means of further informing the conceptual model and the risk assessment. This investigation may be undertaken in a single or a number of successive stages.
Durability	The extent to which a remediation treatment is likely to be effective in reducing or controlling unacceptable risks to a defined level over a period of time.

Effectiveness	The extent to which a remediation treatment successfully reduces or controls unacceptable risks to a defined level.
Environmental impact	The effect of remediation treatments on the quality of the environment during or following remediation.
Exploratory investigation	Preliminary intrusive investigation of a site, designed to facilitate hazard assessment and conducted prior to the detailed investigations required for risk estimation.
<i>Ex situ</i>	Where contaminated material is removed from the ground prior to above-ground treatment or encapsulation and/or disposal on or off-site.
Generic assessment criteria	Criteria derived using general assumptions about the characteristics and behaviour of sources, pathways and receptors. These assumptions will be protective in a range of defined conditions.
Generic quantitative assessment	Risk assessment carried out using generic assumptions to estimate risk or to develop generic assessment criteria.
Harm	Adverse effects on the health of living organisms or other interference with the ecological systems of which they form a part. In the case of humans the definition includes harm to property.
Hazard	A property or situation that in particular circumstances could lead to harm or pollution.
Health criteria value	Benchmark criteria that represent an assessment of levels of exposure that pose a risk to human health. For example, tolerable daily intake (TDI) and index dose.
Implementation plan	A plan that sets out all aspects of design, preparation, implementation, verification, long-term maintenance and monitoring of the remediation.
<i>In situ</i>	Where contaminated material is treated without prior excavation (of solids) or abstraction (of liquids) from the ground.
Large disturbed sample	Sample (usually greater than 2 kilograms in size) taken without any special precautions to maintain the original structure of the sampled material.
Management objectives	Site specific objectives defined by stakeholders that relate to regulatory, financial and commercial matters and the desired outcome of remediation.
MCERTS	The Monitoring Certification Scheme is a quality assurance scheme for providers of monitoring services, equipment and systems, that is administered by the Environment Agency and accredited by UKAS.
Methanogenic	Methane producing.
Monitoring	A continuous or regular period check to determine the ongoing nature and performance of remediation, which includes measurements undertaken for compliance purposes and those undertaken to assess performance.
Non-aqueous phase liquids	Liquids that do not mix readily with water.

Non-targeted sampling	Sampling based on a systematic pattern of sampling points that are evenly distributed across sampling area.
Pathway	A route or means by which a receptor could be, or is exposed to, or affected by a contaminant.
Permeability	A measure of the ability of a medium to allow a fluid (gas or liquid) to pass through it.
Photo-ionisation director	A device that quantifies organic vapours depending on their ionisation potential.
Pollutant linkage	The relationship between a contaminant, pathway and receptor.
Preliminary risk assessment	First tier of risk assessment that develops the initial conceptual model of the site and establishes whether or not there are any potentially unacceptable risks.
Receptor	In general terms, something that could be adversely affected by a contaminant, such as people, an ecological system, property or a water body.
Remediation	Action taken to prevent or minimise, or remedy or mitigate the effects of any identified unacceptable risks.
Response zone	The perforated section of standpipe which allows gas in the unsaturated zone or groundwater below the water table to enter a standpipe.
Risk	A combination of the probability, or frequency of occurrence, of a defined hazard and the magnitude of the consequences of the occurrence.
Risk assessment	The formal process of identifying, assessing and evaluating the health and environmental risks that may be associated with a hazard.
Risk management	The process involved in identifying, assessing and determining risks, and the implementation of actions to mitigate the consequences or probabilities of occurrence.
Site characterisation	The process of gathering information about a site (or group of sites) and its setting(s) for the purpose of assessing and, where necessary, managing health and environmental risks.
Site-specific assessment criteria	Values for concentrations of contaminants that have been derived using detailed site-specific information on the characteristics and behaviour of contaminants, pathways and receptors and that correspond to relevant criteria in relation to harm or pollution for deciding whether there is an unacceptable risk.
Small disturbed sample	Sample (usually 1 to 2 kilograms in size) taken without any special precautions to maintain the original structure of the sampled material.
Source	A hazardous substance or agent (for example a contaminant) which is capable of causing harm.
Supplementary investigation	Investigation carried out subsequent to a detailed investigation for the purpose of refining risk estimates, to assist in the selection of an appropriate remedial strategy, or for detailed (remedial) design purposes.

Targeted sampling	Sampling that is specifically targeted at the location(s) of known or suspect sources of contamination.
Uncertainty	A lack of knowledge about specific factors in a risk or exposure assessment including parameter uncertainty, model uncertainty and scenario uncertainty.
Undisturbed sample	Undisturbed piston samples (often 100mm in diameter) usually obtained from percussive boring equipment.
Verification	The process of demonstrating that the risk has been reduced to meet remediation criteria and objectives based on a quantitative assessment of remediation performance.
Zoning	The process of delineating one or more parts of a site that justify different or specific approaches to sampling on the basis of existing or future conditions.

Appendix 2

Contact details

Association of Consulting Engineers (ACE)

Alliance House
12 Caxton Street
London
SW1H 0QL

Tel: 020 7222 6557
Fax: 020 7222 0750
Email: consult@acenet.co.uk
www.acenet.co.uk

The ACE provides information to enquirers of firms of consulting engineers who may provide services related to contamination. Normal practice is to provide names of a few firms who are members of the Association and close to the land in question. Database covers 500 different specialties including investigation and treatment of contaminated ground, water treatment, sewage treatment, hydrogeology, geotextiles and soil mechanics.

Association of Consulting Scientists Limited (ACS)

PO Box 560
Wembley
Middlesex
HA0 1NN

Tel: 020 8991 4883
Fax: 020 8991 4882
www.consultsci.uku.co.uk

The Members of the Association of Consulting Scientists are independent consultants in science and technology with practices based mainly within the UK. The Association provides a link to those member scientists practicing as consultants and enables the formation of multi-disciplinary teams to address complex problems involving many fields of expertise. Services offered range from accident investigation to radar imaging.

Association of Geotechnical and Geoenvironmental Specialists (AGS)

Forum Court
83 Copers Cope Road
Beckenham
Kent
BR3 1NR

Tel: 0208 658 8212
Fax: 0208 663 0949
Email: ags@ags.org.uk
www.ags.org.uk

Members are both consultants and contractors involved in the geo-environment offering services in ground investigation, contaminated land assessment and remediation, laboratory testing and analysis, environmental audits, hydrogeology and pollution control. Copies of the membership list and details of publications are available from the Administrator.

British Expertise

1 Westminster Palace Gardens
1-7 Artillery Row
London
SW1P 1RJ

Tel: 020 7222 3651
Fax: 020 7222 3664
Email: mail@britishexpertise.org
www.britishexpertise.org

A non-profit making multi disciplinary organisation of almost 300 independent consultancy firms and individuals. British Expertise has an environmental group representing engineers, architects, environmentalists, lawyers, economics and other consultancy disciplines. Direct enquiries are accepted to assist in identifying appropriate consultants.

British Geotechnical Association (BGA)

c/o Institution of Civil Engineers
1 Great George Street
Westminster
London
SW1P 3AA

Tel: 020 7665 2233
Fax: 020 7799 1325
Email: bga@britishgeotech.org.uk
www.britishgeotech.org.uk

The British Geotechnical Association is the principal association for geotechnical engineers in the United Kingdom. It performs the role of the ICE Ground Board, as well as being the UK member of the International Society for Soil Mechanics and Geotechnical Engineering (ISSMGE) and the International Society for Rock Mechanics (ISRM).

British Geological Survey (BGS)

Knigsley Durham Centre
Keyworth
Nottingham
NG12 5GG

Tel: 0115 936 3143
Fax: 0115 936 3276
Email: enquiries@bgs.ac.uk
www.bgs.ac.uk

The British Geological Survey (BGS), formed in 1835, is the world's oldest geological survey. It is the nation's principal supplier of geoscience expertise and custodian of much of the country's geoscientific information. BGS provides objective, impartial and up-to-date geoscientific information, advice and services which meet the needs of customers in the commercial, governmental, and scientific communities of Great Britain and overseas.

Chartered Institute of Environmental Health (CIEH)

Chadwick Court
15 Hatfields
London
SE1 8DJ

Tel: 020 7928 6006
Fax: 020 7827 5862
Email: info@cieh.org
www.cieh.org

The Chartered Institute of Environmental Health (CIEH) is at the forefront of environmental and public health. It sets standards and accredits courses and qualifications for the education of professional members and other environmental health practitioners. It also provides policy advice, runs educational events, publishes books and magazines, and commissions research.

Chartered Institution of Water and Environmental Management (CIWEM)

15 John Street
London
WC1N 2EB

Tel: 020 7831 3110
Fax: 020 7405 4967
Email: admin@ciwem.org
www.ciwem.org

CIWEM is a leading professional and examining body for scientists, engineers, other environmental professionals, who are committed to the application of engineering, scientific or management knowledge and expertise to the provision of works and services designed to further the beneficial management, conservation and improvement of the environment. Produces CIWEM Yearbook which includes general industry information and a listing of consultants in various areas including contaminated land.

Environment Agency (EA)

Rio House
Waterside Drive
Aztec West
Almondsbury
Bristol
BS32 4UD

Tel: 08708 506 506
Email: enquiries@environment-agency.gov.uk
www.environment-agency.gov.uk

The Environment Agency is the leading public body for protecting and improving the environment in England and Wales. It aims to ensure that air, land and water are looked after by everyone in today's society, so that tomorrow's generations inherit a cleaner, healthier world.

Environment and Heritage Service (EHS)

Klondyke Building
Cromac Avenue
Gasworks Business Park
Lower Ormeau Road
Belfast
BT7 2JA

Tel: 0845 302 0008
Fax: 02890 569 548
Email: brian.forrest@doeni.gov.uk
www.ehsni.gov.uk

EHS takes the lead in advising on, and in implementing, the Government's environmental policy and strategy in Northern Ireland. The Agency carries out a range of activities, which promote the Government's key themes of sustainable development, biodiversity and climate change. Their overall aim is to protect and conserve Northern Ireland's natural heritage and built environment, to control pollution and to promote the wider appreciation of the environment and best environmental practices.

Environmental Industries Commission (EIC)

45 Weymouth Street
London
W1G 8ND

Tel: 020 7935 1675
Fax: 020 7486 3455
www.eic-uk.co.uk

The EIC provides environmental technology equipment and services suppliers with a strong and effective voice to influence the debate on the future of the industry among policymakers in Westminster, Whitehall and Brussels. It aims to promote constructive co-operation between the regulated, the regulators and the UK's environmental technology suppliers who serve them.

Environmental Data Services (ENDS)

11-17 Wolverton Gardens
London
W6 7DY

Tel: 020 8267 8100
Fax: 020 8267 8150
Email: post@ends.co.uk
www.ends.co.uk

Holds detailed database of consultants and offers free search service to anyone (including non-members); searches usually produce a minimum of five consultants meeting the criteria provided. ENDS Directory of Environmental Consultants is a detailed directory of over 400 consultancies which includes information on choosing a consultancy. ENDS also publish an analysis of the environmental consultancy market.

Geological Society

Burlington House
Piccadilly
London
W1J 0BG

Tel: 020 7434 9944
Fax: 020 7439 8975
Email: enquiries@geolsoc.org.uk
www.geolsoc.org.uk

The Geological Society combines the functions of a learned society with that of a professional institution and is recognised by the DTI as the regulatory body for geology and geologists. A directory of chartered geologists is published every two years.

Health Protection Agency (HPA)

7th Floor
Holborn Gate
330 High Holborn
London
WC1V 7PP

Tel: 020 7759 2700 / 2701
Fax: 020 7759 2733
Email: webteam@hpa.org.uk
www.hpa.org.uk

The Health Protection Agency (HPA) is an independent body that protects the health and well-being of the population. The Agency plays a critical role in protecting people from infectious diseases and in preventing harm when hazards involving chemicals, poisons or radiation occur.

Institute of Environmental Management & Assessment (IEMA)

St Nicholas House
70 Newport
Lincoln
LN1 3DP

Tel: 01522 540 069
Fax: 01522 540 090
Email: info@iema.net
www.iema.net

The Institute of Environmental Management and Assessment (IEMA) is a not-for-profit organisation established to promote best practice standards in environmental management, auditing and assessment. The IEMA is now a leading international membership-based organisation dedicated to the promotion of sustainable development, and to the professional development of individuals involved in the environmental profession.

Institution of Civil Engineers (ICE)

1 Great George Street
Westminster
London
SW1P 3AA

Tel: 020 7222 7722
Fax: 020 7222 7500
www.ice.org.uk

Produces a publication (though not updated) in conjunction with Institute of Biology, Institution of Chemical Engineers, Royal Society of Chemistry, listing organisations offering consultancy services. Information can be supplied as lists of references, external databases, searches, photocopies of articles, etc. for historical information on sites and published information on contaminated land.

Institution of Structural Engineers (IStructE)

11 Upper Belgrave Street
London
SW1X 8BH

Tel: 0207 235 4535
Fax: 0207 235 4294
www.istructe.org

IStructE is the world's leading professional body for structural engineering. It is the appropriate source of relevant and considered opinion on all structural engineering and public safety issues in the built environment. Its image is one of safety, efficiency and excellence, both of its operations and in the standards of its members. The Institution qualifies its members by examinations that test professional competence in structural engineering design.

Landscape Institute

33 Great Portland Street
London
W1W 8QG

Tel: 020 7299 4500
Fax: 020 7299 4501
Email: mail@landscapeinstitute.org
www.landscapeinstitute.org

The Landscape Institute is the professional body for landscape architects, landscape managers and landscape scientists. The Institute publishes a Directory of Registered Landscape Practices in January each year, which lists practices by area. A short summary of the expertise of each practice is included and further advice on the selection of landscape consultants is available through a nomination service.

National House-Building Council (NHBC)

Buildmark House
Chiltern Avenue
Amersham
HP6 5AP

Tel: 0844 633 1000
Fax: 0844 633 0022
Email: technicalenquiries@nhbc.co.uk
www.nhbcbuilder.co.uk

NHBC is the standard setting body and leading warranty provider for new and newly converted homes in the UK. It provides a broad range of services to the house-building and wider construction industry. NHBC is also internationally recognised as an example of best practice.

Royal Institution of Chartered Surveyors (RICS)

12 Great George Street
Parliament Square
London
SW1P 3AD

Tel: 0870 333 1600
Fax: 020 7334 3811
Email: contactrics@rics.org
www.rics.org

The RICS Information Centre holds a database of members' firms and can search for those offering services required in the appropriate area.

Royal Town Planning Institute (RTPI)

41 Botolph Lane
London
EC3R 8DL

Tel: 020 7929 9494
Fax: 020 7929 9490
Email: online@rtpi.org.uk
www.rtpi.org.uk

Provides information to inquirers about firms of consulting town planners who may provide services in respect of contamination. Normal practice is to provide names of a few firms.

Royal Society of Chemistry (RSC)

Burlington House
Piccadilly
London
W1J 0BN

Tel: 020 7437 8656
Fax: 020 7437 8883
www.rsc.org

The RSC produced a publication in 1988 (not updated) in conjunction with the Institute of Biology, Institution of Chemical Engineers, and Institution of Civil Engineers, listing organisations offering consultancy services for the investigation and assessment of contaminated land.

Scottish Environment Protection Agency (SEPA)

Erskine Court
Castle Business Park
Stirling
FK9 4TR

Tel: 01786 457700
Fax: 01786 446885
www.sepa.org.uk

SEPA is Scotland's environmental regulator and adviser. Their role includes controlling pollution and working with others to protect and improve the environment.

Specialist in Land Condition (SiLC)

c/o Institute of Environmental
Management & Assessment
70 Newport
Lincoln
LN1 3DP

Tel: 01522 540 069
Fax: 01522 540 090
Email: info@iema.net
www.silc.org.uk

A SiLC Professional and Technical Panel was established to develop a system for the registration of individuals completing the Land Condition Record (LCR). An individual who becomes registered will be a "Specialist in Land Condition" and be known as a SiLC. The use of a registered SiLC will give the highest level of credibility to the information that is included in the LCR.

UK Accreditation Services (UKAS)

21-47 High Street
Feltham
Middlesex
TW13 4UN

Tel: 020 8917 8400
Fax: 020 8917 8500
Email: info@ukas.com
www.ukas.com

Technical enquiry office answers specific questions/enquiries relating to laboratories involved in chemical analysis of contaminated land. All accreditation schedules are available from their website.

Appendix 3

The regulatory regimes for Northern Ireland, Wales and Scotland

Northern Ireland

The Northern Ireland Assembly was established as part of the Belfast Agreement and it is the prime source of authority for all devolved/transferred matters (including environment and planning) and has full legislative and executive authority. Devolution powers became the responsibility of the Northern Ireland Assembly on the 2nd December 1999. The Executive was subsequently suspended and Direct Rule restored on the 11th February 2000. Restoration of devolution subsequently took place on 30th May 2000. Twenty four hour suspensions also took place in August and September 2001. On the 14th October 2002 the Assembly was again suspended and then formally dissolved on the 28th April 2003. Subsequently the Assembly was restored to a state of suspension following elections in November 2003 with the Assembly finally being restored on 8th May 2007.

The Environment and Heritage Service (EHS) is the largest Agency within the Department of the Environment (DOE NI), one of the eleven Northern Ireland Departments created in 1999. The EHS takes the lead in advising on, and in implementing, the Government's environmental policy and strategy in Northern Ireland.

The Planning Service, another Agency which comes under the umbrella of the DOE NI, is responsible for developing and implementing Government planning policies and development plans in Northern Ireland.

Part 3 of the Waste and Contaminated Land (Northern Ireland) Order 1997 contains the main legal provisions for the introduction of a contaminated land regime in Northern Ireland. The Order was enacted in 1997 but the regime is not yet in operation. The provisions within Part 3 are virtually identical to those provided by part 2A and would establish a regime whereby local authorities are under a duty to investigate and identify contaminated land and identify those responsible for its remediation.

In terms of provision of technical guidance for regulators to assist them in the determination of contaminated land the DOE NI references the DEFRA SGV Task Force and CLEA publications.

The primary legislation governing planning in Northern Ireland is the Planning (Northern Ireland) Order 1991 (as amended). This is backed up by secondary legislation and planning policy, including planning policy statements (PPSs) and area plans. However there is currently no specific PPS addressing development on potentially contaminated land.

Planning applications are determined by the Planning Service with local councils, along with other government departments, acting as consultees to the approval process.

Despite the lack of guidance the Planning Service, in considering planning applications for brownfield sites, will impose conditions for site investigation and remediation that broadly mirror the requirements of part 3/Part 2A.

Wales

Both the Environment Protection Act 1990 and the Environment Act 1995 were issued on a UK wide basis, so the same principles of Part 2A legislation are applicable. In July 1997 the UK Government published a white paper outlining proposals for devolution. In Wales a referendum was held in September 1997 and the result led to the Government of Wales Act 1998 being issued thus establishing the National Assembly for Wales (NAW) with powers being transferred on 1st July 1999. Since this time subordinate legislation has been introduced in Wales that details how the provisions of an Act of Parliament will apply. Hence the reason for different effects in Wales to that of England.

The elected Assembly Members effectively delegated their powers for implementation of policies and legislation to the Welsh Assembly Government (WAG). One of the subject areas within WAG is Environment Planning & Countryside, which covers the policies and subordinate legislation relevant to land contamination. The preliminary legislation was The Contaminated Land (Wales) Regulations 2001 Welsh Statutory Instrument 2001 No. 2197 (W.157) which came into force on 01st July 2001. This has now been revoked and replaced by The Contaminated Land (Wales) Regulations 2006 Welsh Statutory Instrument 2006 No. 2989 (W.278) which came into force on 10th December 2006. These include the changes for appeals on Remediation Notices, which are required to be made to NAW. The Radioactive Contaminated Land (Modification of Enactments) (Wales) Regulations 2006 were implemented at the same time.

Current Statutory Guidance relevant to Wales is the Part 2A Statutory Guidance on Contaminated Land (2006) issued by WAG. This comprises Guidance previously issued in November 2001 and further guidance to accompany other modifications such as the introduction of radioactivity. The principle regulators of the Part 2A process are Environment Agency Wales and as appropriate the local authority responsible for the site in question. As in England the use of the CLEA UK model and the relevant SGV and TOX reports are applicable in Wales.

In respect of Planning the circular 022/87 (WO) prepared by DETR (Department of Environment, Transport and the Regions) on Development of Contaminated Land remains applicable for outlining the requirements associated with new developments, including change of use. The document states that contamination is a material planning consideration, but is ambiguous in a number of areas. It does however indicate that an investigation will normally be required where the previous history of the site suggests contamination.

Planning Policy Wales (2002) outlines that the physical constraints on the land are to be taken into account at all stages of the planning process and this is in the context of land instability and land contamination. It also explains that LPA's (Local Planning Authorities) should be aware of the requirements of Part 2A and ensure that their policies and decisions are consistent with it. This implies that the methods used in assessing land for Part 2A purposes should be applied within the planning regime. Accordingly the concept of risk assessment as a tool to help direct development on a suitable for use basis is appropriate as in England.

PPS23 does not apply in Wales, however it may be referred to as good practice, though this may be open to challenge. In Wales Technical Advice Notes (TAN) are used as Planning Policy Statements and currently there is no TAN applicable to land contamination in Wales. WAG is considering the preparation of a TAN and it is understood that this will look at the suitability of PPS23 for Wales, though no timetable for delivering this has been made.

Land Contamination: A Guide for Developers prepared on behalf of the Welsh Local Government Association, Environment Agency Wales & WAG was issued in July 2006. Whilst this is not statutory guidance, it helps confirm good practice and broadly details the risk assessment process in line with CLR11 (Model Procedures).

Scotland

Since the passing of the Scotland Act and the official convening of the Scottish Parliament and the Scottish Executive on the 1st July 1999 devolved matters, including the environment and planning, have been the responsibility of Scottish Ministers.

There are two regulatory enforcement bodies in Scotland with duties and powers in terms of identification and remediation of contaminated land and development of brownfield sites; Local Authorities and the Scottish Environment Protection Agency (SEPA) which was established in 1996.

The current structure of local government in Scotland was established by the Local Government (Scotland) Act 1994. Since the passing of the Act Scotland has been divided into 29 unitary authorities and 3 island authorities. It is the responsibility of the Scottish Executive to implement Part 2A of the Environmental Protection Act, 1990. Scottish Ministers therefore implemented The Contaminated Land (Scotland) Regulations 2000 (SI2000/178) (the 2000 Regulations) with

accompanying statutory guidance on the 14th July 2000.

The 2000 Regulations were replaced on the 1st April 2006 by the Contaminated Land (Scotland) 2005 Regulations (the 2005 Regulations). The 2005 Regulations amended Part 2A of the Environmental Protection Act 1990 and the 2000 Regulations in the light of the Water Environment and Water Services (Scotland) Act 2003. Guidance on the 2005 Regulations was published in June 2006 in the form of Paper SE/2006/44 (Statutory Guidance; Edition 2) by the Scottish Executive. The document replaces in its entirety the guidance issued July 2000.

Contaminated land was defined in the 2000 Regulations where *pollution of controlled waters is being, or is likely to be caused*. This meant that any degree of pollution of controlled waters could have resulted in the land being designated as contaminated. The 2005 Regulations addressed the anomaly whereby *trivial* amounts of pollution resulted in land being designated as contaminated by introducing a requirement that pollution be “significant” or likely to be “significant” in relation to the water environment.

Unlike England and Wales the 2005 Regulations do not include radioactive contamination. The Radioactive Contaminated Land (Scotland) Regulations 2007 came into force in Scotland on the 30th October 2007. The Regulations make provision for Part 2A to have effect with modifications for the purpose of the identification and remediation of radioactive contaminated land.

In terms of guidelines for the assessment of contaminated land, CLEA publications and the CLEA model are used to aide identification of potentially contaminated land. The following table summarises the duties and powers of Local Authorities and SEPA under Part 2A.

Local Authority – duties	SEPA – duties
Inspect their areas to identify contaminated land and designate special sites	Provide site specific advice to local authorities on contaminated land
Ensure remediation of land identified as contaminated land	Maintain remediation register of special sites
Maintain remediation registers for contaminated land	Prepare a national report on the state of contaminated land
Consult SEPA on the pollution of the water environment	Require remediation of special sites
Local Authority – powers	SEPA – powers
Recover costs for remediation undertaken itself	Recover costs for remediation undertaken itself

When brownfield or contaminated sites are being developed, Local Authorities require that the need for remediation is determined using guidance provided by Planning Advice Note (PAN) 33.

PAN 33 uses the Suitable for Use Approach. The approach focuses on the risks caused by land contamination and recognises that the risks presented by any given level of contamination will vary greatly according to the use of the land and a wide range of other factors such as the underlying geology.

The Suitable for Use Approach comprises three elements:

- Ensuring that land is suitable for its current use;
- Ensuring that land is made suitable for any new use as planning permission is given for that use; and
- Limiting the requirements for remediation to the work necessary to prevent unacceptable risks to human health or the environment in relation to the current use or future use for which planning permission is being sought.

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Annex 1

Site walkover survey – aide memoire

Site name:

Address:

Code name/no:

Site area (m²):

NGR:

Date inspection undertaken:

Inspected by:

Site contact (name and title):

Weather:

General site description/current site uses

Note **activities** being undertaken on the site, **site access** details and give a description of the **site boundary**. If processes take place on the site you will need to ask rather than just note. Mark these on the plan or draw a sketch map at this stage.

Surface cover of site

(e.g. buildings, hardstanding, grass etc. Potential for surface water infiltration.)

Building and hardstanding materials

Details of materials (type and approximate quantities) that make up site buildings and hardstanding (take some photos).

Visible evidence of contamination

*Look for vegetation dieback, discoloured ground, seepage of odorous/discoloured liquid. Any evidence of gas protection measures (vent pipes/air bricks) – **take photos**. Look at the land adjacent to the site.*

Presence of vegetation and invasive weeds

Record presence condition of trees, plants and shrubs etc. Look for evidence of invasive weeds [Japanese Knotweed; Giant Hogweed; Himalayan Balsom on land and Australian swamp stonecrop; Parrot's feather and floating pennywort in surface water bodies]. See Environment Agency website for Guidance for control of invasive weeds which includes illustration.

Presence of wildlife

Record presence of nesting birds. Is the site within an area of ecological importance e.g. SSSI or National Park. Is Wildlife on-site protected in accordance with the Wildlife and Countryside Act 1981 and 1985 – see Defra website for information on the Wildlife and Countryside Act.

Presence of asbestos

Age of building, pipe lagging, ceiling tiles; brake pads; if evident what state of repair is it in? Has there been an asbestos survey undertaken on the site? Implications for redevelopment?

Presence of PCBs

(Polychlorinated biphenyls, production banned since 1979 but still may be present on-site as a transformer coolant in electrical components. Require specialist disposal by incineration). Has there been a survey? Is there any correspondence with the Electricity Company?

Storage of materials and old tanks

(Check for evidence of wastes and chemicals stored both above and below ground, mark location of storage areas on-site plan.) Are any above ground tanks bunded, what is the condition of the bund, any staining? Are there any underground storage tanks which have been decommissioned? Were they removed? Were they backfilled? Was any ground testing done at the time?

Services

Overhead or buried services? (overhead wires, sewers, gas main, petrol interceptors, where do drains discharge to?) Are service plans available on-site? Are any surface water drains in sensitive areas, e.g. by storage areas?

History of use

Cite evidence, conclusions and sources. There may be relevant street/house/locality or pub names within 250m of the site. Have a look.

Geology, hydrology, hydrogeology

Before the visit make sure you know the basic environmental setting of the site and check that it is consistent with your observations.

Site geology

Describe any surface outcrops/exposures or exposures of soils/rocks in any areas of excavations, cuttings etc.

Any previous investigations (ask on-site, e.g. when extensions built, when tanks excavated)

(contaminative or geotechnical.) Any previous audits, Environment Agency Pollution prevention audits.

Site topography

Flat, sloping etc. Are there any obvious discontinuities within the site or between the site and its neighbours. Any cuttings, embankments, mounds?

Surface water bodies and courses

(Name, type, quality.)

Hydrogeology

(e.g. wells, abstraction, seepages, aquifers.)

Any other relevant information

(Include information on any underground structures or on the presence of any trees.)

Site neighbours

Nature of surrounding land

(e.g. industrial, residential, commercial, SSSIs.)

Approximate distance to nearest properties

a) industrial

b) residential: have there been any complaints? have these been resolved? Were the Local Authority involved? Was any enforcement action taken?

c) commercial

Observations on neighbouring sites

(Note: e.g. spillages, apparent poor site management.)

Photos taken

Note the picture number together with a brief description stating the direction of view, what you are taking the photo of and for, other points of interest in foreground/background etc. It may be easier to do this as annotations on a site plan.

Picture No.	Description

Annex 2

Site sensitivity assessment for the water environment

A Groundwater

It is Important that the characterisation of site sensitivity is logical, transparent, robust and repeatable. A scheme describing terms of sensitivity for groundwater, surface waters and ecology is present below. The assessment of site sensitivity by personnel with an appropriate, relevant technical background will increase the technical rigour and repeatability of the assessment.

Sensitivity assessment	Standard response	Implications/need for further work <i>(subject to nature of source and pathway)</i>
H1 (Very high)	Highly vulnerable aquifer, actively used in vicinity of site with short travel times to sources of supply or sensitive watercourses. Likely to be within an inner or outer groundwater protection zone (Zones I or II under EA protection policy). All contaminant releases to the ground environment of concern.	Extensive groundwater and soil clean-up or removal is likely to be needed if a source and pathway exist. Potential for major on-site and off-site liabilities. Further, detailed risk assessment essential and is likely to be required by the Regulators. Could be long-term residual liabilities with major cost implications and potential high risk of prosecution.
H2 (High)	Major or minor vulnerable aquifer with probable use nearby (either direct abstraction or baseflow to sensitive watercourses and springs). Likely to be within Outer or Source Catchment protection zones (Zones II or III). Most contaminant releases to the ground environment of concern.	Significant groundwater remediation measures may be required, after detailed risk assessment, which is likely to be required by the Regulators. Soil decontamination or isolation probably necessary. Potential for significant on-site and off-site liabilities, including treatment and/or replacement of local potable water supplies. Substantial cost implications and potential moderate/high risk of prosecution.
M1 (Moderately high)	Recognised major or minor aquifer, moderately vulnerable, with probable use (either direct or via baseflow to a sensitive watercourse). Within formal protection zone or catchment of authorised abstractions for potable or other high quality uses. Minor, short-term releases of contaminants may be tolerable.	Following risk assessment, soil decontamination or isolation may be required. Localised groundwater clean-up may be needed but large scale clean-up unlikely unless source is substantial and toxic. Possible off-site liabilities such as replacement/treatment of local potable water supplies. Moderate cost implications and potential moderate risk of prosecution.
M2 (Moderate)	Minor aquifer, low to moderately vulnerable, but with possible uses in general area, particularly for domestic supplies. May provide pathway to surface water.	Risk assessment may indicate need for localised clean up/isolation of soil and groundwater only, but may be some off-site liabilities e.g. local potable water supplies. Moderate to low cost implications. Potential prosecution less likely.
L1 (Low)	Permeable strata/minor aquifer near surface, but no apparent use and low vulnerability (may also be a significant aquifer but downgraded by long-term/permanent degradation of water quality). May provide pathway to surface watercourse at distance.	Localised clean-up/isolation of soil and groundwater only. Unlikely to be significant off-site liabilities or action by statutory authorities with respect to groundwater. Low cost implications.
L2 (Very low)	Not a recognised aquifer, but strata beneath site may retain a small amount of contaminated liquid but there is likely to be limited vertical penetration. High potential for surface runoff or ponding.	Clean-up/isolation of soil and contained groundwater only, in immediate vicinity of release. Unlikely to be off-site liabilities or action by statutory authorities with respect to groundwater. Low cost implications.

B Surface water (excluding coastal waters)

Sensitivity assessment	Standard response	Implications/need for further work <i>(subject to nature of source and pathway and no short circuiting by artificial drainage systems)</i>
H1 (Very high)	High quality watercourse (GQA A or B) within close proximity (less than 250m) of site or with potential for rapid transmission of pollutants to that watercourse via a fissured aquifer, or interconnected unclassified drain or stream.	Potential for major pollution incident with fish kills, risk to river users etc. Major cost implications for remediation measures and with respect to penalties on prosecution. Potential for major adverse publicity.
H2 (High)	Site within catchment and reasonable proximity (less than 500m) of high quality watercourse (GQA A/B) or with potential transmission of pollutants via baseflow from an aquifer with little subsurface attenuation or via an interconnected unclassified drain or stream.	Potential for significant pollution incident that requires remedial measures and likely to involve a prosecution and adverse publicity. Substantial cost implications.
M1 (Moderately high)	Site within catchment and reasonable proximity (less than 500m) of a moderate quality watercourse (GQA C/D) or 500-1000m of a high quality watercourse (GQA A/B). Also where there is potential transmission of pollutants via baseflow with little subsurface attenuation or via an interconnected unclassified drain or stream.	Potential for significant pollution incident that requires remediation measures. Possible prosecution, particularly if contamination is likely to be visible or result in public complaints.
M2 (Moderate)	Site within catchment of and relatively close (less than 1000m) to moderate or poor quality (GQA C to F) watercourse that may be subject to planned improvement by attainment of surface water quality objectives. May be potential for transmission of pollutants via baseflow from a highly permeable formation.	Minor incidents are unlikely to attract third party liabilities, but action by statutory authorities likely if contamination is visible or repeated.
L1 (Low)	Within catchment of and over 250m from generally poor quality watercourse (GQA E or F) that is unlikely to improved by current or foreseeable surface water quality objectives or at distance (over 1000m) from a good quality watercourse with no interconnecting drains or baseflow from fissured strata.	Unlikely to be third party liabilities or action from statutory authorities from surface water viewpoint.
L2 (Very low)	No surface water within general area of the site (at least 250m) or closed drainage within site. Little or no potential for significant transmission via baseflow and no interconnecting drains.	Liabilities restricted to site itself (localised soil contamination or ponding) or associated with groundwater.

C Coastal waters

Sensitivity assessment	Standard response	Implications/need for further work <i>(subject to nature of source and pathway and no short circuiting by artificial drainage systems)</i>
H1 (Very high)	Within 100m of a sensitive coastal water, that is, a recognised bathing water, a “more sensitive area” (as defined under the Urban Wastewater Treatment Directive) or a marine SSSI or at a greater distance but with a direct connection via a stream or a highly fissured aquifer to such a coastal water with the potential for rapid flow to that water.	Potential for major environmental health risks and ecological damage. Probability of high remedial costs, prosecution and adverse publicity.
H2 (High)	As above, within 250m or with a relatively rapid route of transmission or within 100m of a “less sensitive area”.	
M1 (Moderately high)	Within 500m of a bathing water or a defined sensitive area (see above); with possibility of diffuse flow via groundwater seepages at coastline or with connection via nearby watercourses.	LESS DATA AVAILABLE FOR COASTAL SITES TO GIVE GENERALISED ASSESSMENTS OF POTENTIAL LIABILITIES.
M2 (Moderate)	Within 500m of a coastal water (undefined), with possibility of diffuse flow via groundwater seepages at coastline or with connection via nearby watercourses.	
L1 (Low)	No coastline nearby (within 1km), but with possibility of diffuse groundwater seepages at coastline or connection via nearby watercourses.	Liabilities initially associated with watercourses or groundwaters.
L2 (Very low)	No coastline nearby (within 1km) and/or no direct connection via surface or ground water.	No liabilities likely.

D Artificial drainage systems

Sensitivity assessment	Standard response	Implications/need for further work <i>(subject to nature of source and pathway and no short circuiting by artificial drainage systems)</i>
H1 (Very high)	Extensive land use/industrial history, successive building development. Steep surface slopes (rapid travel times with little opportunity for dilution/interception facilities) or close proximity (within 250m) to surface watercourses or high sensitivity groundwater. Former mining areas where subsurface mine drains are present or suspected. Detailed drainage records absent.	Probability of interconnection of artificial and natural drainage systems, with consequent risks to sewers, surface and ground water. Potential unconsented connections and discharges on- and off-site with third party pipes/structures, risk of third party action and additional effluent treatment costs. Potential damage to site fabric and structures due to leakages and collapse. Major cost implications for investigation and implementation of remedial measures. Drainage investigation and risk assessment essential.
H2 (High)	As above, but shallower slopes (longer retention times in drains) or more distant (over 250m) to surface watercourses or with detailed records of drainage systems.	As above, but potentially lower investigatory and remedial costs. Drainage investigation and risk assessment essential.
M1 (Moderately high)	More than one phase of site development with limited historic records of drainage systems (sewers, surface water, pipelines). Over 250m from surface watercourse.	As above, but less extensive drainage investigation and reduced investigation and remedial costs.
M2 (Moderate)	More than one phase of site development with detailed historic records of drainage systems (sewers, surface water, pipelines).	As above, costs likely to be dependent on-site processes and degree of maintenance of existing drainage systems.
L1 (Low)	Recent (greenfield) development, with recorded and low intensity drainage systems or older sites with thoroughly investigated and recorded drainage systems, drainage risk assessment and implementation of remedial measures. Within 250m of surface watercourses or on low permeability strata. No mine drains.	Leakages from drains may contaminate soil locally and eventually reach a watercourse. Low risk of third party action.
L2 (Very low)	Recent (greenfield) development, with recorded and low intensity drainage systems, or older sites with thoroughly investigated/recorded drainage systems, drainage risk assessment and implementation of remedial measures. Remote from surface watercourses, all drainage to adopted sewers and with no permeable strata within 10m of the site surface. No mine drains.	Leakages from drains may contaminate soil locally.

Annex 3

Key contaminants associated with industrial uses of land

[Reproduced from R&D66: 2000]

Comprehensive lists of contaminants associated with industrial uses of land appear in each of the Department of the Environment Industry Profiles. The number of contaminants associated with industrial uses varies, with some profiles listing over 100 different substances. The most significant contaminants associated with each, selected on the basis of frequency of occurrence, existence of information on hazards and availability of analytical methods are listed in the two following tables: Metals, semi-inorganic chemicals; and Organic chemicals. The tables are taken from the CLR report on contaminants for the assessment of land (CLR8).

Metals, semi-metals and inorganic chemicals associated with industrial uses of land

Industry	Key Contaminants																					
	Metals and semi-metals										Inorganic chemicals											
	As	Ba	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	V	Zn	CN-free	CN-complex	NO ₃ ⁻	SO ₄ ²⁻	S ²⁻	Asbestos	B	pH	So	
Airports					✓	✓							✓					✓			✓	
Animal and animal products processing works	✓			✓	✓											✓						
Asbestos manufacturing works				✓	✓																	
Ceramics, cement and asphalt manufacturing works	✓			✓	✓	✓	✓	✓			✓						✓	✓			✓	
Charcoal works	✓			✓	✓	✓	✓	✓		✓	✓				✓			✓			✓	
Chemical works: coatings and printing inks manufacturing works		✓		✓	✓	✓	✓	✓			✓					✓		✓			✓	✓
Chemical works: cosmetics and toiletries manufacturing works				✓							✓						✓	✓			✓	
Chemical works: disinfectants manufacturing works		✓			✓	✓	✓	✓			✓					✓					✓	
Chemical works: explosives, propellants and pyrotechnics manufacturing works	✓	✓			✓	✓	✓	✓			✓				✓			✓	✓		✓	
Chemical works: fertiliser manufacturing works				✓	✓	✓		✓			✓							✓			✓	
Chemical works: fine chemicals manufacturing works	✓			✓	✓		✓								✓			✓				✓

Metals, semi-metals and inorganic chemicals associated with industrial uses of land

Industry	Key Contaminants																					
	Metals and semi-metals							Inorganic chemicals														
	As	Ba	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	V	Zn	CN-free	CN-complex	NO ₃ ⁻	SO ₄ ²⁻	S ²⁻	Asbestos	B	pH	So	
Chemical works: inorganic chemicals manufacturing works	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓		✓	✓	✓	✓	✓		✓	
Chemical works: linoleum vinyl and bitumen-based floor covering manufacturing works	✓										✓	✓					✓	✓			✓	
Chemical works: mastics, sealants, adhesives and roofing felt manufacturing works	✓	✓			✓	✓	✓	✓			✓	✓			✓	✓		✓			✓	
Chemical works: organic chemicals manufacturing works	✓				✓	✓	✓		✓		✓	✓	✓			✓	✓	✓			✓	
Chemical works: pesticides manufacturing works	✓				✓	✓	✓	✓			✓	✓			✓	✓		✓			✓	
Chemical works: pharmaceuticals manufacturing works	✓				✓	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓			✓	✓
Chemical works: rubber processing works (including works manufacturing tyres and other rubber products)																	✓					✓
Chemical works: soap and detergent manufacturing works																					✓	
Dockyards and dockland	✓			✓	✓	✓	✓	✓	✓		✓	✓				✓	✓	✓				✓
Dry cleaners	✓			✓	✓	✓	✓	✓	✓		✓	✓			✓	✓		✓			✓	

Metals, semi-metals and inorganic chemicals associated with industrial uses of land

Industry	Key Contaminants																					
	Metals and semi-metals										Inorganic chemicals											
	As	Ba	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	V	Zn	CN-free	CN-complex	NO ₃ ⁻	SO ₄ ²⁻	S ²⁻	Asbestos	B	pH	So	
Engineering works: aircraft manufacturing works				✓	✓	✓	✓		✓		✓	✓	✓		✓	✓		✓		✓		
Engineering works: electrical and electronic equipment manufacturing works (including works manufacturing equipment containing PCBs)	✓			✓	✓	✓	✓	✓	✓		✓	✓			✓	✓	✓	✓	✓		✓	
Engineering works: mechanical engineering and ordnance works	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓		✓	✓	✓		
Engineering works: railway engineering works	✓			✓	✓	✓	✓	✓		✓	✓	✓	✓		✓	✓		✓	✓	✓		
Engineering works: shipbuilding repair and shipbreaking (including naval shipyards)	✓				✓	✓	✓				✓	✓	✓					✓		✓		
Engineering works: vehicle manufacturing works				✓	✓	✓	✓		✓		✓	✓	✓		✓	✓	✓	✓		✓		
Fibreglass and fibreglass resin manufacturing works	✓			✓	✓	✓	✓		✓		✓	✓	✓		✓	✓		✓		✓		
Gasworks, coke works and other coal carbonisation plants	✓			✓	✓	✓	✓	✓		✓	✓	✓	✓				✓	✓		✓		✓
Glass manufacturing works	✓			✓	✓	✓	✓	✓			✓	✓	✓					✓		✓		

Metals, semi-metals and inorganic chemicals associated with industrial uses of land

Industry	Key Contaminants																								
	Metals and semi-metals											Inorganic chemicals			pH	So									
	As	Ba	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	V	Zn	CN-free	CN-complex			NO ₃ ⁻	SO ₄ ²⁻	S ²⁻	Asbestos	B				
Metal manufacturing, refining and finishing works: electroplating and other metal finishing works				✓	✓	✓	✓	✓			✓	✓	✓			✓	✓	✓	✓	✓		✓			
Metal manufacturing, refining and finishing works: iron and steel works	✓				✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓		✓		✓	
Metal manufacturing, refining and finishing works: lead works	✓			✓	✓	✓	✓	✓			✓	✓	✓			✓	✓	✓	✓	✓		✓			
Metal manufacturing, refining and finishing works: non-ferrous metals(excluding lead works)				✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓		✓			
Metal manufacturing, refining and finishing works: precious metal recovery works	✓			✓	✓	✓	✓	✓			✓	✓	✓			✓	✓	✓	✓	✓		✓			
Oil refineries and bulk storage of crude oil and petroleum products	✓					✓	✓	✓			✓	✓	✓			✓	✓	✓	✓	✓		✓			
Photographic processing industry	✓			✓	✓	✓	✓	✓			✓	✓	✓			✓	✓	✓	✓	✓		✓			
Power stations (excluding nuclear power stations)	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓			✓	✓	✓	✓	✓		✓			
Printing and bookbinding works	✓			✓	✓	✓	✓	✓			✓	✓	✓			✓	✓	✓	✓	✓		✓			
Pulp and paper manufacturing works	✓			✓	✓	✓	✓	✓			✓	✓	✓			✓	✓	✓	✓	✓		✓			
Railway land	✓			✓	✓	✓	✓	✓			✓	✓	✓			✓	✓	✓	✓	✓		✓			

Metals, semi-metals and inorganic chemicals associated with industrial uses of land

Industry	Key Contaminants																					
	Metals and semi-metals							Inorganic chemicals														
	As	Ba	Be	Cd	Cr	Cu	Pb	Hg	Ni	Se	V	Zn	CN-free	CN-complex	NO ₃ ⁻	SO ₄ ²⁻	S ²⁻	Asbestos	B	pH	So	
Road vehicle servicing and repair: garages and filling stations	✓				✓	✓	✓				✓	✓						✓			✓	
Road vehicle servicing and repair: transport and haulage centres	✓				✓	✓	✓			✓	✓	✓						✓			✓	✓
Sewage works and sewage farms	✓			✓	✓	✓	✓	✓			✓	✓	✓		✓	✓	✓	✓			✓	
Textile works and dye works	✓			✓	✓	✓		✓							✓	✓		✓	✓		✓	
Timber products manufacturing works	✓			✓		✓	✓				✓	✓			✓	✓			✓			
Timber treatment works	✓				✓	✓					✓	✓					✓		✓		✓	
Waste recycling, treatment and disposal sites: drum and tank cleaning and recycling plants																	✓	✓			✓	
Waste recycling, treatment and disposal sites: hazardous waste treatment plants	✓			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓			✓	
Waste recycling, treatment and disposal sites: landfills and other waste treatment or waste disposal sites	✓			✓	✓	✓	✓		✓		✓	✓					✓	✓			✓	
Waste recycling, treatment and disposal sites: solvent recovery works				✓	✓	✓	✓				✓	✓			✓						✓	
Waste recycling, treatment and disposal sites: metal recycling sites	✓			✓	✓	✓	✓	✓	✓		✓	✓	✓					✓			✓	✓

Organic chemicals associated with industrial uses of land

Industry	Key Contaminants													
	Phenol	Propanone	Chlorophenols	Oil/fuel hydrocarbons	Aromatic hydrocarbons	PAHs	Chlorinated aliphatic hydrocarbons	Hexachloro-cyclohexane	Dieldrin	Chlorinated Aromatic hydrocarbons	PCBs	Dioxins & furans	Organolead compounds	Organotin compounds
Airports	✓			✓	✓		✓				✓			
Animal and animal products processing works	✓				✓	✓		✓						
Asbestos manufacturing works					✓	✓					✓			
Ceramics, cement and asphalt manufacturing works		✓		✓		✓				✓	✓			
Charcoal works		✓			✓					✓	✓			
Chemical works: coatings and printing inks manufacturing works	✓				✓	✓							✓	
Chemical works: cosmetics and toiletries manufacturing works		✓			✓	✓								
Chemical works: disinfectants manufacturing works	✓				✓	✓					✓			
Chemical works: explosives, propellants and pyrotechnics manufacturing works	✓	✓		✓	✓					✓	✓			
Chemical works: fertiliser manufacturing works				✓		✓								
Chemical works: fine chemicals manufacturing works	✓	✓			✓	✓					✓			
Chemical works: inorganic chemicals manufacturing works						✓								
Chemical works: linoleum vinyl and bitumen-based floor covering manufacturing works	✓			✓	✓	✓								✓
Chemical works: mastics, sealants, adhesives and roofing felt manufacturing works	✓			✓	✓	✓								

Organic chemicals associated with industrial uses of land

Industry	Key Contaminants													
	Phenol	Propanone	Chlorophenols	Oil/fuel hydrocarbons	Aromatic hydrocarbons	PAHs	Chlorinated Aliphatic hydrocarbons	Hexachloro-cyclohexane	Dieldrin	Chlorinated Aromatic hydrocarbons	PCBs	Dioxins & furans	Organolead compounds	Organotin compounds
Chemical works: organic chemicals manufacturing works	✓										✓			
Chemical works: pesticides manufacturing works	✓		✓						✓		✓			✓
Chemical works: pharmaceuticals manufacturing works				✓		✓				✓	✓			
Chemical works: rubber processing works (including works manufacturing tyres and other rubber products)	✓			✓						✓	✓			
Chemical works: soap and detergent manufacturing works		✓		✓		✓						✓		
Dockyards and dockland	✓					✓				✓	✓			
Dry cleaners				✓						✓	✓			
Engineering works: aircraft manufacturing works				✓						✓	✓			
Engineering works: electrical and electronic equipment manufacturing works (including works manufacturing equipment containing PCBs)				✓						✓	✓			
Engineering works: mechanical engineering and ordnance works	✓	✓				✓				✓	✓			
Engineering works: railway engineering works						✓				✓	✓			
Engineering works: shipbuilding repair and shipbreaking (including naval shipyards)		✓		✓									✓	
Engineering works: vehicle manufacturing works	✓	✓		✓		✓								
Fibreglass and fibreglass resin manufacturing works	✓	✓												✓

Organic chemicals associated with industrial uses of land

Industry	Key Contaminants													
	Phenol	Propanone	Chlorophenols	Oil/fuel hydrocarbons	Aromatic hydrocarbons	PAHs	Chlorinated Aliphatic hydrocarbons	Hexachloro-cyclohexane	Dieldrin	Chlorinated Aromatic hydrocarbons	PCBs	Dioxins & furans	Organolead compounds	Organotin compounds
Gasworks, coke works and other coal carbonisation plants	✓													
Glass manufacturing works		✓					✓				✓			
Metal manufacturing, refining and finishing works: electroplating and other metal finishing works	✓			✓			✓							
Metal manufacturing, refining and finishing works: iron and steel works	✓			✓		✓					✓			
Metal manufacturing, refining and finishing works: lead works						✓					✓			
Metal manufacturing, refining and finishing works: non-ferrous metals (excluding lead works)				✓		✓					✓			
Metal manufacturing, refining and finishing works: precious metal recovery works				✓							✓			
Oil refineries and bulk storage of crude oil and petroleum products	✓	✓		✓	✓						✓	✓		
Photographic processing industry		✓			✓						✓			
Power stations (excluding nuclear power stations)				✓		✓					✓			
Printing and bookbinding works		✓			✓						✓			
Pulp and paper manufacturing works				✓							✓			
Railway land						✓					✓			
Road vehicle servicing and repair: garages and filling stations						✓					✓			✓

Organic chemicals associated with industrial uses of land

Industry	Key Contaminants													
	Phenol	Propanone	Chlorophenols	Oil/fuel hydrocarbons	Aromatic hydrocarbons	PAHs	Chlorinated Aliphatic hydrocarbons	Hexachloro-cyclohexane	Dieldrin	Chlorinated Aromatic hydrocarbons	PCBs	Dioxins & furans	Organolead compounds	Organotin compounds
Road vehicle servicing and repair: transport and haulage centres		✓			✓	✓	✓				✓		✓	
Sewage works and sewage farms				✓			✓				✓			
Textile works and dye works	✓	✓		✓	✓			✓			✓			
Timber products manufacturing works	✓	✓			✓	✓								
Timber treatment works	✓		✓	✓		✓	✓						✓	
Waste recycling, treatment and disposal sites: drum and tank cleaning and recycling plants		✓			✓						✓			
Waste recycling, treatment and disposal sites: hazardous waste treatment plants	✓						✓		✓		✓			
Waste recycling, treatment and disposal sites: landfills and other waste treatment or waste disposal sites				✓		✓					✓	✓		
Waste recycling, treatment and disposal sites: solvent recovery works														
Waste recycling, treatment and disposal sites: metal recycling sites				✓			✓				✓			

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Acetone	Acetone, also known as propanone, is used as a solvent and in the manufacture of methyl methacrylate, methyl isobutylketone and other chemicals. It is produced in the manufacture	Moderate toxicity.	Water pollutant.					
Acidity/alkalinity as indicated by measurement of pH	The pH of a soil reflects its acidity (pH<7) or alkalinity (pH>7). A pH value of 7 is neutral. Most soils tend to have an early neutral pH. Acidic industrial wastes include pyritic wastes from coal and non-metaliferous mining, china clay waste, acidic boiler ash and cinders, spent oxides, acid tars and sulphuric acid produced during the manufacture of town gas. Alkali wastes include quarry waste, fly ash, ammoniacal liquors from town gas manufacture and certain other industrial process wastes. Acidic or alkaline conditions could be found on almost any kind of site. The pH value of a soil affects the mobility and hence availability for uptake by vegetables of a number of potential soil contaminants.	Extreme pH soils are corrosive. Risk through dermal contact and ingestion.	Acidic and strongly alkaline conditions may increase mobility of contaminants.	May reduce plant growth through increasing the availability of phytotoxic metals.	Acid ground conditions may corrode building materials such as concrete, plastics, metals, and limestone.			
Aliphatic halocarbons	Chlorinated aliphatic hydrocarbons (aliphatic hydrocarbons) are used in industry for a variety of purposes. Chlorinated solvents are the most important members of this group with respect to the assessment of contaminated land and include carbon tetrachloride, chloroform, 1, 2-dichloroethane, 1, 1, 1-trichloroethane, hexachlorobut-1, 3-diene, vinyl chloride, trichloroethene and tetrachloroethene. Elevated levels of aliphatic halocarbons may originate from industrial processes, especially chemical works, coatings, printing works, cosmetic manufacturers, oil refineries, textile and dye works, timber treatment works and solvent recovery works.	Toxic. Principal risk through inhalation. Vinyl chloride is carcinogenic.	Water pollutant.	Phytotoxic.	Deleterious affect on plastic or rubbers.			

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Ammonium compounds	Elevated levels of ammonium compounds or ammonia may originate from fertilisers, explosives, plastic industries and gas works.	Although ammonia and ammonium compounds are toxic, human health is not considered a priority target.	Water pollutant. List II substance.	Phytotoxic.	Adversely affects building materials.			
Aromatic hydrocarbons	Aromatic hydrocarbons include benzene, methylbenzene, toluene and xylene. This group is often referred to as 'BTEX' compounds. Elevated levels of aromatic hydrocarbons may originate from industrial processes, for example coatings, printing works manufacture, engineering works, gas works, oil refineries and solvent recovery works.	Toxic. Principal risk through inhalation.	Water pollutant. List I substance.	Phytotoxic.	Deleterious to building materials such as plastics through mechanisms such as swelling.			
Aromatic halocarbons	This group which is also termed chlorinated aromatic hydrocarbons includes chlorobenzenes and chlorotoluenes. Elevated levels of these may be encountered at many industrial sites.	Toxic. Risk through dermal contact, inhalation and ingestion.	Water pollutant.	May accumulate in plant roots.	Can be deleterious to plastic and rubbers.			
Arsenic	Elevated levels of arsenic may originate from industrial processes, for example mineral smelting, agricultural preparations and waste disposal. Arsenic may also be associated with the ceramic, electronic, metallurgic, timber treatment, textile and tanning industries.	Toxic. Carcinogenic. Risk through dermal contact, ingestion and inhalation.	Water pollutant. List II substance.	May reduce plant growth. Uptake can cause contamination of vegetables.		✓	✓	
Asbestos	Asbestos is a generic term for a number of naturally fibrous silicates, including crocidolite (blue), amosite (brown), and chrysotile (white asbestos). Asbestos can be found at many industrial sites due to its use as an insulation material. Heavy engineering sites, dockyards, railway engineering works, gasworks and asbestos factories appear to be especially prone to asbestos contamination.	Toxic. Carcinogenic. Principal risk through inhalation.						

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Barium	Elevated levels of barium may originate from coatings and printing inks manufacture, vehicle manufacture and glassmaking.		Water pollutant. List II substance.			✓		
Beryllium	Elevated levels of beryllium may originate from a range of industrial processes. Naturally high levels of beryllium may be associated with natural mineralisation of certain granitic rocks, where beryl is the only common beryllium-bearing mineral.	Soluble beryllium compounds are toxic. Risk through inhalation, ingestion and dermal contact.	Water pollutant. List II substance.	Possibly phytotoxic. Uptake can cause contamination of vegetables.		✓ (but elevated levels from this source are rare)		
Boron	Elevated boron levels may be associated with engineering works, glass works, explosives manufacture, textile and dye works and timber treatment.		Water pollutant. List II substance.	Phytotoxic.		✓		
Cadmium	Elevated levels of cadmium may originate from a range of industrial processes and may occur naturally as a result of mineralisation, particularly of rocks bearing lead, zinc and copper minerals.	Toxic. Suspected carcinogen. Risk through inhalation and ingestion.	Water pollutant. List I substance.	Suspected phytotoxic. Uptake can cause contamination of vegetables.		✓		✓
Carbon dioxide	Carbon dioxide is a gas formed as a result of oxidation or combustion of organic materials or from respiration. It is normally produced together with methane from anaerobic degradation of organic materials. It may be produced by oxidation of recent sediments, coal and other carbonaceous rocks. Carbon dioxide may also be liberated from a dissolved state in groundwater and from acid water interaction with carbonate rocks such as limestone. Carbon dioxide is frequently encountered on industrial sites, especially at waste disposal (landfill) sites and coal workings. However, carbon dioxide and methane may be generated at any site where made ground (fill) is present.	Toxic and asphyxiant gas.	Dissolves readily in water.	May be phototoxic in elevated concentrations.		✓		

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Chloride	Elevated levels of chlorides may originate from a large variety of industrial processes and may occur naturally.	Human health is not considered a priority target.	Water pollutant. List II substance.	Phytotoxic at elevated concentrations.	Detrimental affect on building materials.	✓		
Chlorinated phenols	Includes monochlorophenols, dichlorophenols, trichlorophenols, tetrachlorophenols as well as pentachlorophenol and its compounds. Chlorophenols are used for a variety of domestic, agricultural and industrial purposes, especially the manufacture of herbicides/biocides. Pentachlorophenol is used as a wood preservative and maybe found at timber treatment works and chemical manufacturing plants.	Toxic. Risk through ingestion and dermal contact with dust.	Water pollutant. List I substance.	Phytotoxic.	Some chlorophenols may permeate polythene.			
Chromium	Elevated levels of chromium may originate for industrial processes, while naturally high levels may be associated with ultrabasic rocks. Chromium exists in several oxidation states, of which Cr III and Cr VI are the most stable. At soil pH of less than 5.5, CrVI is generally reduced to Cr III precipitating insoluble oxides and hydroxides. In the context of protection of human health Cr VI is the most significant state.	Cr III – low toxicity. Low risk of allergic reaction through dermal contact. Cr VI – toxic, carcinogenic. Risk through dermal contact, inhalation and ingestion.	Water pollutant. List II substance. List I substance.	Phytotoxic, although unlikely due to prevalence of Cr III in natural soil.		✓		
Copper	Elevated levels of copper may originate from a variety of industrial operations. High levels of copper may be encountered through natural geological strata and mineralisation processes. The phytotoxicity of copper is highest in acidic soils. The effect of copper, nickel and zinc may be additive.	Toxic only at elevated levels.	Water pollutant. List II substance.	Highly phytotoxic.	Corrosive to rubber.	✓	✓	
Cyanide	Cyanide can be present in soils as complex cyanides, free cyanide or as thiocyanate. Elevated levels of cyanide may originate from many industrial sites, for example gas works, plating works, heat treatment works, photography and pigment manufacture. Elevated levels of cyanide may occasionally reflect natural biochemical processes in soil.	Complex Cyanides – toxic free. Cyanides – very toxic. Thiocyanate – low toxicity.	Water pollutant. List II substance.	Phytotoxic.	Complex cyanides are reported to have detrimental effect on building materials.	✓	✓	

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally		Affected by	
		Humans	Water	Plants	Other	pH	Organic matter		
Dioxins and furans	The term 'dioxins and furans' refers to a group of 210 polychlorinated dibenzo-p-dioxins and furans (PCDD/PCDF) of which 17 are considered to have toxicological significance. Dioxins and furans are organic compounds produced during combustion processes and are thus present in incinerator stack emissions and emissions from burning of coal. Dioxins and furans are present as contaminants in pentachlorophenol and may therefore be found on the sites of disinfectant manufacturing works, power stations, hazardous waste disposal sites, landfill sites, solvent recovery works and timber treatment works. Most dioxins and furans released into the atmosphere ultimately accumulate in soils and sediments.	Toxic. Risk through inhalation and ingestion.	Water pollutant. List I substance.	Uptake can cause contamination of vegetables.					
Lead	Elevated levels of lead may originate from industrial land uses and from exhaust emissions from petrol vehicles. Elevated levels of lead may be encountered through natural mineralisation processes.	Toxic. Risk through inhalation and ingestion.	Water pollutant. Phytotoxic. Uptake may result in food contamination.			✓			
Mercury	Elevated levels of mercury may be present from industrial processes. Elevated levels may also be found in association with black shales and from binding in organic soils.	Toxic. Irritant. Risk through dermal contact, ingestion and inhalation.	Water pollutant. List I substance.	Phytotoxic. Uptake can cause contamination of vegetables.		✓		✓	
Methane	Methane is a flammable gas produced by the aerobic degradation of organic material. It is frequently encountered on industrial sites, especially at waste disposal (landfill) sites, and in the vicinity of coal workings. However, methane and carbon dioxide may be generated at any site where made ground (fill) is present. Methane may be generated from the degradation of natural organic remains in recent sediments and from conversion of organic matter under the influence of elevated temperatures (e.g. in natural gas associated with coal and petroleum). Natural sources of methane which may be encountered within the UK also include swamps, marshes and fresh water lakes.	Risk of asphyxiation due to oxygen displacement.		High concentrations of methane can cause vegetation die-back.	Risk of fire and explosion.	✓			

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Nickel	Elevated levels of nickel may originate from industrial processes. Elevated levels of nickel may be found naturally, particularly in association with ultra basic rocks.	Toxic at elevated levels. Irritant. Risk through dermal contact, inhalation and ingestion.	Water pollutant. List II substance.	Phytotoxic. Uptake can cause contamination of vegetables.	Fire risk with dust or powder. Risk of toxic fumes if fires are lit on heavily contaminated sites.	✓	✓	
Nitrate	Elevated nitrate levels may be associated with sewage sludge applications to land. Although nitrate is used as a fertiliser, elevated levels in water can cause eutrophication.		Water pollutant.			✓		
Oil/fuel hydrocarbons	All industrial sites have the potential to be contaminated by hydrocarbons such as mineral oils, diesel fuel and petroleum spirits etc. Typically, these substances are found on airports, dockyards, engineering works, gas works, oil refineries, bulk storage facilities and vehicle fuelling, servicing and repairing facilities. Elevated levels of hydrocarbons may be associated with the natural geology, especially from oil source rocks such as oil shales, algal and black limestones, black shales and coals.	Toxic. Risk through dermal contact, ingestion and inhalation.	Water pollutant. List I substance.	May reduce plant growth. Uptake can cause contamination of vegetables.	Flammable. May adversely affect building materials, especially rubber and plastics.	✓		
Organometallics	Organolead, organomercury and organotin compounds are considered the most important representatives of this group. Organotin compounds are possible soil contaminants at industrial sites such as timber treatment works and organic chemical manufacturing works. Organolead compounds are important anti-knock additives for gasoline additives and will often be encountered where petroleum is found. Organomercury compounds are frequently used in the preparation of other organometallic compounds.	Most, if not all, organometallic compounds are toxic to humans.	Water pollutants.	Uptake can cause contamination of vegetables.				

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Selenium	Elevated levels of selenium may originate from industrial processes, for example mining, smelting and refining of sulphide ores and coal combustion. Selenium may also be associated with the manufacture of electronic components, glass, plastics, ceramics, lubricants and waste disposal sites.	Toxic in soluble compound forms or as elemental dust. Risk through ingestion, inhalation and dermal contact.	Water pollutant. List II substance.	May be phytotoxic. Uptake can cause contamination of vegetables.		✓		
Silver	Elevated levels of silver may originate from industrial processes, natural mineralisation processes and in hydrothermal veins.	Metallic silver considered to be non toxic. Low toxic risk through dermal contact, ingestion and inhalation of silver compounds.	Water pollutant. List II substance.	May be phytotoxic.		✓		
Sulphate	Elevated levels of sulphate may be associated with colliery spoil, clinker from old power stations, rubble and slag. Elevated levels may also occur naturally in association with dark calcareous pyritic clays, marshy soils and from oil shale residues.	Not considered a priority contaminant with respect to human health.	Water pollutant. List II substance.	Can be phytotoxic.	Detrimental to building materials.	✓	✓	
Sulphide	Elevated levels of sulphide may originate from a range of industrial processes, as well as from natural mineralisation.	Not identified as a priority contaminant with respect to human health. However, can generate highly toxic hydrogen sulphide under acid conditions.	Water pollutant.	Can be phytotoxic.	Not a hazard to construction materials in the absence of oxygen and moisture. High acidity caused by biogenic oxidation to sulphate can especially affect cast iron pipework.	✓	✓	

Background information on key contaminants [Reproduced from R&D66: 2000]

Contaminants	Sources	Receptors				Occurs naturally	Affected by	
		Humans	Water	Plants	Other		pH	Organic matter
Sulphur	Sulphur (and its associated species, sulphates, sulphides and sulphites) may be found at many industrial sites including chemical works, railway engineering works, gas works, dockyards, iron and steel works. Free sulphur may occur naturally in sedimentary rocks, limestones and around hot springs. Native sulphur, however, is unlikely to be encountered in appreciable quantities in the UK.	Toxic in excessive concentrations. Risk through dermal contact and inhalation. Combustible, giving rise to highly toxic sulphur dioxide.	Not deemed a priority contaminant with respect to the water environment.	Conversion to sulphide and sulphate could result in phytotoxicity.	Conversion to sulphide and sulphate could lead to attack on building materials.	✓		
Thallium	Elevated levels of thallium may originate from industrial processes and from natural mineralisation processes in some sulphide and selenium ores.	Thallium compounds may be very highly toxic. Risk through dermal contact, ingestion and inhalation.	Water pollutant. List II substance.	May be phytotoxic.				
Vanadium	Elevated levels of vanadium may originate from industrial processes as well as from natural mineralisation processes.	Toxic if inhaled as dust or fumes.	Water pollutant. List II substance.	Uptake can cause contamination of vegetables.		✓ (but relatively uncommon)		
Zinc	Elevated levels of zinc may originate from a range of industrial processes as well as from natural mineralisation processes. The phytotoxicity of zinc is increased in acid conditions. The effects of phytotoxicity of copper, nickel and zinc may be cumulative.	Essentially non-toxic unless in high concentrations.	Water pollutant. List II substance.	Phytotoxic.	Fire and explosion risk from zinc dust in damp conditions.	✓	✓	

Annex 4

Qualitative risk assessment

A4.1 Context

CIRIA RP599 Contaminated Land Risk Assessment Guide, provides a guide to good practice in assessing risks from contaminated land. This distinguishes between the processes of:

- **Risk estimation** – process of estimating risk that defined receptors will suffer harm.
- **Risk evaluation** – process of evaluating need for risk management action, with regard to magnitude of risks the level of uncertainty and, if remedial action is needed the objectives and broad costs and benefits.

At Phase 1 the **risk estimation** will take the form of a qualitative risk assessment, which will be entirely based on the conceptual model for each potential end-use of the site. Comments on level of uncertainty will also need to be included for each source-pathway-target linkage to allow the confidence in the assessed risks to be understood. The results of the qualitative risk assessment will allow the **risk evaluation** to be concisely described in the following chapters.

At Phase 2 (or later stages) the **risk estimation** will comprise a number of sequential steps all based on the conceptual model:

1. Interpretation of site investigation data with respect to relevant generic assessment criteria (Tier 1);
2. Interpretation of site investigation data with respect to site specific assessment criteria if appropriate (Tier 2);
3. Site specific qualitative risk assessment including input from Tier 1 and Tier 2 [this procedure].

Comments on level of uncertainty will also be required for through the interpretation of site investigation data and the qualitative risk assessment. The results of the qualitative risk assessment will allow the **risk evaluation** to be concisely described.

A4.2 Introduction

The following classification has been developed from DOE Guide to Risk Assessment and Risk Management for Environmental Protection and the Statutory Guidance on Contaminated Land (Defra September 2006). The methodology differs from that presented in Contaminated Land Risk Assessment, A Guide to Good Practice (CIRIA C552, 2001), particularly in terms of the definitions of classification of consequence, which include a consideration of immediacy of hazards.

The key to the classification is that the designation of risk is based upon the consideration of both:

- a) **the magnitude of the potential consequence (i.e. severity).**
[takes into account both the potential severity of the hazard and the sensitivity of the receptor]
- b) **the magnitude of probability (i.e. likelihood).**
[takes into account both the presence of the hazard and receptor and the integrity of the pathway]

A4.3 Classification of consequence

Classification	Definition	Examples
Severe	<p>Highly elevated concentrations likely to result in “significant harm” to human health as defined by the EPA 1990, Part 2A, if exposure occurs.</p> <p>Equivalent to EA Category 1 pollution incident including persistent and/or extensive effects on water quality; leading to closure of a potable abstraction point; major impact on amenity value or major damage to agriculture or commerce.</p> <p>Major damage to aquatic or other ecosystems, which is likely to result in a substantial adverse change in its functioning or harm to a species of special interest that endangers the long-term maintenance of the population.</p> <p>Catastrophic damage to crops, buildings or property.</p>	<p>Significant harm to humans is defined in circular 01/2006 as death, disease*, serious injury, genetic mutation, birth defects or the impairment of reproductive functions.</p> <p>Major fish kill in surface water from large spillage of contaminants from site.</p> <p>Highly elevated concentrations of List I and II substances present in groundwater close to small potable abstraction (high sensitivity).</p> <p>Explosion, causing building collapse (can also equate to immediate human health risk if buildings are occupied).</p>
Medium	<p>Elevated concentrations which could result in “significant harm” to human health as defined by the EPA 1990, Part 2A if exposure occurs.</p> <p>Equivalent to EA Category 2 pollution incident including significant effect on water quality; notification required to abstractors; reduction in amenity value or significant damage to agriculture or commerce.</p> <p>Significant damage to aquatic or other ecosystems, which may result in a substantial adverse change in its functioning or harm to a species of special interest that may endanger the long-term maintenance of the population.</p> <p>Significant damage to crops, buildings or property.</p>	<p>Significant harm to humans is defined in circular 01/2006 as death, disease*, serious injury, genetic mutation, birth defects or the impairment of reproductive functions.</p> <p>Damage to building rendering it unsafe to occupy e.g. foundation damage resulting in instability.</p> <p>Ingress of contaminants through plastic potable water pipes.</p>
Mild	<p>Exposure to human health unlikely to lead to “significant harm”.</p> <p>Equivalent to EA Category 3 pollution incident including minimal or short lived effect on water quality; marginal effect on amenity value, agriculture or commerce.</p> <p>Minor or short lived damage to aquatic or other ecosystems, which is unlikely to result in a substantial adverse change in its functioning or harm to a species of special interest that would endanger the long-term maintenance of the population.</p> <p>Minor damage to crops, buildings or property.</p>	<p>Exposure could lead to slight short-term effects (e.g. mild skin rash).</p> <p>Surface spalling of concrete.</p>
Minor	<p>No measurable effect on humans.</p> <p>Equivalent to insubstantial pollution incident with no observed effect on water quality or ecosystems.</p> <p>Repairable effects of damage to buildings, structures and services.</p>	<p>The loss of plants in a landscaping scheme.</p> <p>Discoloration of concrete.</p>

* For these purposes, disease is to be taken to mean an unhealthy condition of the body or a part of it and can include, for example, cancer, liver dysfunction or extensive skin ailments. Mental dysfunction is included only insofar as it is attributable to the effects of a pollutant on the body of the person concerned.

A4.4 Classification of probability

(only applies if there is a possibility of a pollutant linkage being present)

Category	Definition	Examples
High likelihood	There is pollutant linkage and an event would appear very likely in the short-term and almost inevitable over the long-term, or there is evidence at the receptor of harm or pollution.	<p>a) Elevated concentrations of toxic contaminants are present in soils in the top 0.5m in a residential garden.</p> <p>b) Ground/groundwater contamination could be present from chemical works, containing a number of USTs, having been in operation on the same site for over 50 years.</p>
Likely	There is pollutant linkage and all the elements are present and in the right place which means that it is probable that an event will occur. Circumstances are such that an event is not inevitable, but possible in the short-term and likely over the long-term.	<p>a) Elevated concentrations of toxic contaminants are present in soils at depths of 0.5-1.0m in a residential garden, or the top 0.5m in public open space.</p> <p>b) Ground/groundwater contamination could be present from an industrial site containing a UST present between 1970 and 1990. The tank is known to be single skin. There is no evidence of leakage although there are no records of integrity tests.</p>
Low likelihood	There is pollutant linkage and circumstances are possible under which an event could occur. However, it is by no means certain that even over a long period such an event would take place, and is less likely in the shorter term.	<p>a) Elevated concentrations of toxic contaminants are present in soils at depths >1m in a residential garden, or 0.5-1.0m in public open space.</p> <p>b) Ground/groundwater contamination could be present on a light industrial unit constructed in the 1990s containing a UST in operation over the last 10 years – the tank is double skinned but there is no integrity testing or evidence of leakage.</p>
Unlikely	There is pollutant linkage but circumstances are such that it is improbable that an event would occur even in the very long-term.	<p>a) Elevated concentrations of toxic contaminants are present below hardstanding.</p> <p>b) Light industrial unit <10 yrs old containing a double-skinned UST with annual integrity testing results available.</p>

Note: A pollution linkage must first be established before probability is classified. If there is no pollution linkage then there is no potential risk. If there is no pollution linkage then there is no need to apply tests for probability and consequence.

For example if there is surface contamination and a major aquifer is present at depth, but this major aquifer is overlain by an aquiclude of significant thickness then there is no pollution linkage and the risks to the major aquifer are not assessed. The report should identify both the source and the receptor but state that because there is no linkage there are no potential risks.

A.4.5 The classification of risk

Probability (Likelihood)	Consequence			
	Severe	Medium	Mild	Minor
High likelihood	Very high risk	High risk	Moderate risk	Low risk
Likely	High risk	Moderate risk	Moderate/low risk	Low risk
Low likelihood	Moderate risk	Moderate/low risk	Low risk	Very low risk
Unlikely	Moderate/low risk	Low risk	Very low risk	Very low risk

A4.5.1 Description of the classified risks

Very high risk

There is a high probability that severe harm could arise to a designated receptor from an identified hazard at the site without remediation action OR there is evidence that severe harm to a designated receptor is already occurring. Realisation of that risk is likely to present a substantial liability to be site owner/or occupier. Investigation is required as a matter of urgency and remediation works likely to follow in the short-term.

High risk

Harm is likely to arise to a designated receptor from an identified hazard at the site without remediation action. Realisation of the risk is likely to present a substantial liability to the site owner/or occupier. Investigation is required as a matter of urgency to clarify the risk. Remediation works may be necessary in the short-term and are likely over the longer term.

Moderate risk

It is possible that harm could arise to a designated receptor from an identified hazard. However, it is either relatively unlikely that any such harm would be severe, and if any harm were to occur it is more likely, that the harm would be relatively mild. Further investigative work is normally required to clarify the risk and to determine the potential liability to site owner/occupier. Some remediation works may be required in the longer term.

Low risk

It is possible that harm could arise to a designated receptor from identified hazard, but it is likely at worst, that this harm if realised would normally be mild. It is unlikely that the site owner/or occupier would face substantial liabilities from such a risk. Further investigative work (which is likely to be limited) to clarify the risk may be required. Any subsequent remediation works are likely to be relatively limited.

Very low risk

It is a low possibility that harm could arise to a designated receptor, but it is likely at worst, that this harm if realised would normally be mild or minor.

No potential risk

There is no potential risk if no pollution linkage has been established.

Definitions	
Hazard	A property or situation which in certain circumstances could lead to harm. [The properties of different hazards must be assessed in relation to their potential to affect the various different receptors].
Risk	A combination of the probability or frequency of the occurrences of a defined hazard AND the magnitude of the consequences of that occurrence.
Probability	The mathematical expression of the chance of a particular event in a given period of time [e.g. probability of 0.2 is equivalent to 20% or a 1 in 5 chance].
Likelihood	Probability; the state or fact of being likely.
Consequences	The adverse effects (or harm) arising from a defined hazard which impairs the quality of the environment or human health in the short or longer term.
Pollution linkage	An identified pathway is capable of exposing a receptor to a contaminant and that contaminant is capable of harming the receptor.

Annex 5

Risk assessment models

A5.1 Choosing the model

The majority of quantitative risk assessment models concentrate on examining variations in the pathway from the source to the receptor. It is important to ensure the conceptual model of your site is consistent with the risk assessment model being used. For instance if your site has contamination in the soil below the groundwater table a model examining migration of contaminants from the near surface soil through an unsaturated zone below impacting the groundwater is inappropriate. The pathways and conceptual model for some commonly used models are described briefly later in these notes. An understanding of the models is essential both when entering data and also when interpreting the results. The ability of the model to examine very specific feature such as fractured flow in chalk or free product is not necessarily described but is often an important consideration.

A5.2 Types of model

Models are generally targeted to examine a particular receptor in land and water – these are generally either Human Health or a Controlled Water. Some models such as BP RISC and RBCA can look at both these aspects although they are generally (but not always) calculated on separate runs.

There are two types of model, deterministic models and probabilistic models:

- Deterministic models use a single equation to relate the exposure at the source with that at the receptor. These are relatively simple calculations which are suitable for use where the data is limited. In using these models conservative assumptions should generally be made, although this means the answers can be overly conservative.
- Probabilistic (or stochastic) models treat the data in a more statistical way and thus instead of providing a single number output they provide a distribution. These models overcome the overly conservative outputs of deterministic models. However, they require a lot more data to be used appropriately.

In addition models can often be run in either of two modes:

- Forward calculations which use known concentrations in the subsurface to predict impacts at receptors;
- Back-calculations which use acceptable concentrations or doses at the receptor to predict acceptable concentrations in the subsurface.

The choice of computer model and mode to run it in will depend on the complexity of the conceptual model being considered. Quantitative risk assessments therefore range from the simple to the complex, but to ensure consistency of approach all assessments need to be completed and/or reviewed by staff experienced in using risk assessment packages, in addition to technical review.

A5.3 Typical data requirements

Data requirements vary with the complexity of the conceptual model and also with the computer model selected, but the types of information listed overleaf would typically be used in an assessment.

Typical Parameters for Human Health Risk Quantitative Modelling	Data source
Depth, extent and concentrations of contaminants in unsaturated, saturated, vapour, dissolved and or free phase source	Site Data
Geological properties (porosity, soil organic matter (SOM), air and water content) for source layer and all above strata	Direct from site data or estimated from good geotechnical descriptions
Hydrogeological properties (groundwater levels, gradient, hydraulic conductivity) for source layer and all above strata	Direct from site data (hydraulic conductivity occasionally estimated)
Use of the site – current and proposed	Site Data
Amount of hard cover – current and proposed	Site Data
Building parameters (no. of air exchanges, fraction of cracks etc.) – current and proposed	Direct from site data or estimated from description of buildings
Exposure parameters (body weight, exposure duration, exposure frequency exposure rates, times and skin areas etc.)	Exposure databases including CLEA, BP RISC, RBCA
Chemical properties of contaminants including toxicological parameters and degradation rates (if published)	Chemical databases including CLEA, BP RISC, RBCA

Typical Parameters for Risk to Controlled Waters Quantitative Modelling	Data source
Detailed sensitivity information including local and regional aquifer hydrogeology and chemistry	Additional Phase 1 information
Detailed receptor information including pumping rates, screen depths and use for abstraction wells, and low flow and uses of surface water	Additional Phase 1 information
Depth, extent and concentrations of contaminants in unsaturated, saturated, vapour, dissolved and or free phase source	Site Data
Geological properties (porosity, fraction of organic carbon (FOC), air and water content) for source layer and all potentially impacted underlying strata	Direct from site data or estimated from good geotechnical descriptions
Hydrogeological properties (groundwater levels, gradient, hydraulic conductivity) for source layer and all potentially impacted underlying strata	Direct from site data (hydraulic conductivity occasionally estimated)
Amount of hard cover and recharge information – current and proposed	Site Data and additional Phase 1 information
Chemical properties of contaminants including toxicological parameters and degradation rates (if published)	Chemical databases including CLEA, BP RISC, RBCA

Precis of Risk Assessment Models

These are the opinions of the authors and do not necessarily represent the opinions of NHBC, the Environment Agency or CIEH.

Model	Sources considered	Receptors considered	Pathways considered (human health)	Pathways considered (controlled waters)	Limitations	Main strengths	Free phase?
Risc v4.03 (BP)	Soil, groundwater, surface water.	Humans (site users, construction workers, trespassers, neighbours, swimmers). Groundwater and surface water.	Soil ingestion, dermal contact. Vegetable ingestion (uptake from soil and irrigation water). Volatilisation from soil, transport to indoor air and outdoor air. Volatilisation from groundwater to indoor air. Ingestion from private water supply. Ingestion, inhalation and dermal contact (in shower, garden sprinkler). Ingestion and dermal contact (swimmers).	Leaching to groundwater from unsaturated zone. Leaching to groundwater from saturated zone. Lateral transport of contaminants dissolved in groundwater.	<i>All Pathways</i> Not based on UK methodologies. <i>Human Health</i> Default receptor parameters and exposure scenarios database do not include UK data – can be modified. Default chemical parameters database does not include UK toxicity data – can be modified. Probabilistic option is different to UK approach.	<i>All Pathways</i> Allows simultaneous calculation for TPH fractions. Extensive database of physical chemical properties. <i>Human Health</i> Includes a volatilisation from groundwater model.	Can model risk from free phase, but not transport of free phase.
CONSIM 2 (Golder Associates and EA)	Soil, groundwater, soakaway.	Groundwater, soakaway.	Not applicable.	Leaching to groundwater from unsaturated zone. Migration to groundwater from saturated zone. Lateral transport of contaminants dissolved in groundwater.	No 'backwards' calculation to predict remedial targets – can be done by iteration.	Methodology consistent with UK approach. Probabilistic model. Option to model in fractured rock. Extensive database of contaminant properties.	Can model risk from free phase, but not transport of free phase.

Precis of Risk Assessment Models

These are the opinions of the authors and do not necessarily represent the opinions of NHBC, the Environment Agency or CIEH.

Model	Sources considered	Receptors considered	Pathways considered (human health)	Pathways considered (controlled waters)	Limitations	Main strengths	Free phase?
CLEA UK beta (EA) <i>Note: Final version not currently available – likely to change.</i>	Soil.	Humans (site users).	Soil ingestion, dermal contact. Vegetable ingestion (uptake from soil). Volatilisation from soil, transport to indoor air and outdoor air.	Not applicable.	Only models one exposure scenario in each run. Run time typically slow. No option to consider bioavailability.	Is the most consistent with the UK approach. CLEA standard exposure scenarios included as default settings. Most parameters can be adjusted to allow site specific risk variation. No charge for use.	No.
RCLEA	Soil.	Humans (site users).	Whole body irradiation, irradiation through dermal contact. Vegetable ingestion (uptake from soil), transport to indoor air and outdoor air.	Not applicable.	Point sources cannot be taken into account. Application to real sites not yet in public domain.	Uses the same basic exposure assumptions as CLEA. Simple to use in generic format. Can be used in site specific format to create new land uses. No charge for use.	Not applicable.
Remedial Targets Methodology 2006 (EA)	Soil, groundwater.	Groundwater, surface water.	Not applicable.	Leaching to pore water in unsaturated zone. Transport of pore water to saturated zone. Lateral transport of dissolved contaminants in aquifer.	Only models one contaminant at a time. No database of contaminant properties. Not ideal for modelling transport in fractured rock. Not probabilistic.	Methodology is UK approach. Backward calculation to predict remedial thresholds. No charge for use.	Can model risk from free phase, but not transport of free phase.

Precis of Risk Assessment Models

These are the opinions of the authors and do not necessarily represent the opinions of NHBC, the Environment Agency or CIEH.

Model	Sources considered	Receptors considered	Pathways considered (human health)	Pathways considered (controlled waters)	Limitations	Main strengths	Free phase?
RAM (ESI)	Soil, groundwater.	Groundwater, surface water.	Not applicable.	Leaching to pore water in unsaturated zone. Transport of pore water to saturated zone. Lateral transport of dissolved contaminants in aquifer. Can be customised for site specific pathways.	Requires separate add-in for probabilistic functionality.	Methodology based on UK approach. Multiple contaminants can be modelled in one run. Can model flow in multiple hydrogeological units.	Can model risk from free phase, but not transport of free phase.
GasSim (Golder Associates and EA)	Landfill waste.	Off-site soil gas. Off-site humans (chronic risk). Flares/gas plant. Atmosphere.	Generation of gas from waste, migration through cap and liner. Lateral migration of gas and vapour within unsaturated zone. Soil and derived dust ingestion and dermal contact. Dust inhalation, indoor and outdoor. Vapour inhalation, indoor and outdoor. Vegetable ingestion (uptake from soil).	Not applicable.	Not primarily intended as a contaminated land assessment tool. Requires tonnage inputs of different waste types, which may not be available for historic sites. Users require knowledge of landfill engineering and complex air dispersion modelling.	Methodology is UK approach. Includes four standard CLEA exposure scenarios.	Not applicable.

Precis of Risk Assessment Models

These are the opinions of the authors and do not necessarily represent the opinions of NHBC, the Environment Agency or CIEH.

Model	Sources considered	Receptors considered	Pathways considered (human health)	Pathways considered (controlled waters)	Limitations	Main strengths	Free phase?
RAM (ESI)	Soil, groundwater.	Groundwater, surface water.	Not applicable.	Leaching to pore water in unsaturated zone. Transport of pore water to saturated zone. Lateral transport of dissolved contaminants in aquifer. Can be customised for site specific pathways.	Requires separate add-in for probabilistic functionality.	Methodology based on UK approach. Multiple contaminants can be modelled in one run. Can model flow in multiple hydrogeological units.	Can model risk from free phase, but not transport of free phase.
GasSim (Golder Associates and EA)	Landfill waste.	Off-site soil gas. Off-site humans (chronic risk). Flares/gas plant. Atmosphere.	Generation of gas from waste, migration through cap and liner. Lateral migration of gas and vapour within unsaturated zone. Soil and derived dust ingestion and dermal contact. Dust inhalation, indoor and outdoor. Vapour inhalation, indoor and outdoor. Vegetable ingestion (uptake from soil).	Not applicable.	Not primarily intended as a contaminated land assessment tool. Requires tonnage inputs of different waste types, which may not be available for historic sites. Users require knowledge of landfill engineering and complex air dispersion modelling.	Methodology is UK approach. Includes four standard CLEA exposure scenarios.	Not applicable.

Precis of Risk Assessment Models

These are the opinions of the authors and do not necessarily represent the opinions of NHBC, the Environment Agency or CIEH.

Model	Sources considered	Receptors considered	Pathways considered (human health)	Pathways considered (controlled waters)	Limitations	Main strengths	Free phase?
RISC-HUMAN v3.2 (Van Hall Insituut)	Soil, groundwater, sediment, surface water.	Humans (site users).	Soil ingestion, dermal contact. Volatilisation from soil, transport to indoor air and outdoor air. Inhalation of soil dust. Vegetable uptake. Volatilisation from groundwater, transport to indoor air. Ingestion from private water supply (direct or from permeation of pipes). Inhalation and dermal contact (in shower). Ingestion of water and suspended matter, dermal contact (swimmers). Ingestion of fish, meat and dairy produce. Leaching from sediment in to surface water (see related pathways above).	Not applicable.	Default chemical parameters database does not include UK physical toxicity data – can be modified. Default receptor parameters and exposure scenarios database do not include UK data – can be modified. Not based on UK methodologies.	Can create sub-sites with different land uses. Sophisticated vapour model with a number of conceptual models.	Models LNAPL vapour risk from free phase in unsaturated zone.

Precis of Risk Assessment Models

These are the opinions of the authors and do not necessarily represent the opinions of NHBC, the Environment Agency or CIEH.

Model	Sources considered	Receptors considered	Pathways considered (human health)	Pathways considered (controlled waters)	Limitations	Main strengths	Free phase?
SNIFFER (Scottish & Northern Ireland Forum for Environmental Research)	Soil.	Humans (site users).	Soil ingestion. Vegetable uptake. Volatilisation from soil to indoor and outdoor air.	Not applicable.	Does not include dermal contact pathway. Simple vapour model requires calculation of dilution factor to be consistent with UK approach. Only models one contaminant at a time. No database of chemical parameters.	Includes bioaccessibility option. Methodology is based on UK approach.	No.

A5.3.1 Web Addresses for Further Information and Downloads

Model	Web address
Risc v4.03 (BP)	www.bprisc.com www.groundwatersoftware.com/software/risk/risc/risc.htm
CONSIM 2 (Golder Associates and EA)	www.consim.co.uk
CLEA UK beta (EA)	www.environment-agency.gov.uk/subjects/landquality/113813/672771/1166388/?version=1&lang=e
Remedial Targets Methodology 2006 (EA)	www.environment-agency.gov.uk/subjects/landquality/113813/887579/887905/?lang=e
RAM (ESI)	www.esinternational.com/downloads/index.php
GasSim (Golder Associates and EA)	www.gassim.co.uk
LandSim (Golder Associates and EA)	www.landsim.co.uk
RBCA Toolkit – chemical releases (GSI International)	www.gsi-net.com/software.asp
RISC-HUMAN v3.2 (Van Hall Insituut)	www.risc-site.nl/index.html?riscmainFrame=download.htm
SNIFFER (Scottish & Northern Ireland Forum for Environmental Research)	www.sniffer.org.uk

Annex 6

Risk assessment, perception and communication

A6.1 Background

The management of contaminated land is founded upon a risk based approach. Such an approach is systematic, objective and should provide a scientifically sound, robust and defensible basis on which the options for mitigating such risks can be considered. The scientific and technical aspects concerned with this assessment are generally well known and understood by the specialist parties involved. However, perhaps what is less well recognised, particularly by problem holders and their consultants, is the need for and mechanisms of, communication with all stakeholders, including non specialists such as the public, in this process.

A6.2 Principles of stakeholder dialogue

It is important to recognise that when contaminated land projects are initiated, an appropriate degree of attention must be given to dialogue with stakeholders. Such a dialogue must be an inclusive process involving all groups who may have an interest in the outcome of the project. This may run counter to the instincts of some problem holders, but experience has shown that a properly conducted process, involving all stakeholders (including those who are often deliberately excluded) will often maximise the “buy-in” of stakeholders and thus ensure that the solutions arrived at will be supported and will survive over the long-term.

The principles of effective stakeholder dialogue can be summarised as:

- Identifying who all the stakeholders are;
- Recognising why you are engaged in the process;
- Clearly defining what you are trying to achieve; and
- Determining how you will attain those objectives.

A6.3 The involvement of stakeholders

There are several ways in which information between stakeholders can be obtained and exchanged. Each of these has their own particular characteristics and thus influences the potential outcome. It is therefore important that before engaging with stakeholders, consideration must be given to what all parties are likely to want to come away with from any such involvement. So for example, if the problem holder determines that they want only to provide information to stakeholders they may choose to provide limited information by means of a simple announcement. They may not wish to gather or listen to any views of the other stakeholders. The results of such “involvement” are likely to depend upon degree of authority of the problem holder and the perceptions of that authority by stakeholders. However, there is a real possibility that stakeholders may react adversely to such a one-way communication and positions will become polarised as a result.

Therefore at the commencement of the process it is important to be clear about what objectives there are for both the problem holder and the various stakeholders. This will then enable determination of what type of engagement is most appropriate. So for example, awareness raising or information giving will tend to be one way communication with specific objectives (e.g. of simply providing the results of a decision or explaining some issue to change prevailing attitudes). Two-way communication becomes an essential element where engagement involves consultation, involvement or partnership. These processes involve an increasing level of engagement with stakeholders.

There are occasions however when serious consideration must be given to not entering into a dialogue with stakeholders. For example, if a decision that cannot be changed has been made, a 'consultation' process will merely raise expectations and will inevitably disappoint. Similarly if there is no time available, no commitment from senior management, or if key stakeholders will not attend, there is no real prospect of success for a process of 'dialogue'.

In 2003 the government (HM Treasury and Cabinet Office) listed five principles for good risk management, namely:

- Openness and transparency – make public; risk assessment, the decision making process, admission of mistakes.
- Involvement – actively involve significant stakeholders, two-way communication at all stages, clarification through open discussion, balance conflicting views.
- Act proportionately and consistently – action to be proportionate to protection needed and targeted to risk. Consistent approach to risk. Precautionary principle. Revisit decisions as knowledge changes.
- Evidence based decisions – consider all evidence and qualify before making decisions. Seek impartial/informed advice. Absence of evidence is not absence of threat.
- Responsibility – those that impose risk also take responsibility for control and consequences of inadequacy. Where feasible give individuals choice (where others not exposed to disproportionate risk/cost). Identify where responsibility lies.

A6.4 The risk assessment process

The process of risk assessment in contaminated land projects (as described in the main text of R&D66: 2008) is generally well developed, understood and delivered by the many specialists involved in the area. The use of simple tools has improved consistency in qualitative assessment (see R&D66: 2008 Section 1.7) and the continuing development of numerical systems (see R&D66: 2008 Section 2.8 and Annex 4) has led to widespread acceptance (at least in the industry) of the value and validity of quantitative risk assessments.

However, there is a common failing within problem holders and their consultants in understanding that this stepwise process of risk assessment, which to some appears straightforward, and scientifically robust, is not so logical to many other stakeholders. It does appear to be a commonly adopted (and wrong) position that because the 'expert' assessment shows the level of risk to be 'acceptably low' this should be automatically and universally accepted by other stakeholders (who are necessarily less 'expert'). Such a position fails to recognise that factors other than the technical assessment can have a significant influence on people's perception of risk. In fact "Perception is Reality" [Sniffer 1999].

A6.5 Risk perception

A6.5.1 General

People with different social, economic and cultural backgrounds living in different places will perceive risks in different ways which reflect their own particular knowledge and their environment. That is, people's response to a particular hazard depends upon their perception of the hazard and their knowledge/awareness of both themselves, and "society" to deal with that hazard.

The risk perceived by people may also reflect; the potential for the hazard to be controlled, the potential for catastrophe and their "dread" of that hazard. So for example if a site has radioactive contamination associated with it, the perceived level of risk is likely to be high, reflecting peoples dread of radioactivity. Such dread reflects for example the known effects of fallout from nuclear explosions and visions of Hiroshima. The less familiar people are with a hazard and the less control they have over the potential for exposure, the greater the perception of the risk.

A6.5.2 Voluntary risk

Perception may also be affected by whether or not exposure to the risk is voluntary (when people are more prepared to accept risk, or their perception of such voluntary risk is less than when they have no choice about the matter). For example the risk of knowingly ingesting known carcinogens directly into your lungs several times a day is perceived to be lower by smokers because this activity is undertaken voluntarily. This must be contrasted for example with the circumstances where residents are told that they have been living on the site of historic contamination where for example polyaromatic hydrocarbons are present at concentrations above background levels. The combination of the dread associated with the term 'carcinogenic' and the involuntary nature of the exposure will serve to increase the perception of this risk well above the level of any technical assessment.

A6.5.3 Expert assessment

Risk assessment carried out by experts can not be "absolute" because:

- Experts themselves may be biased or motivated by their own values/self interests; and
- This expert assessment takes no account of the beliefs of 'the public'.

What often takes place in the contaminated land debate is that the expert defines the objective risk and then tries to align the perception of the public and the regulator with this version of reality (or "the truth"). As described above, often no recognition is made by the expert those factors other than the technical estimation of risk influences how people perceive and behave in the face of particular hazards.

Decisions taken with regard to a particular risk are not driven only by calculation of probability. For example, relative estimates of risk have not figured at all in the debate about genetically modified organisms. A major factor in the opposition of this technology is a lack of trust in those "in control" of the technology or regulating the risks. It has also been shown that an important element in the perception of risk is the particular personal disposition of an individual – i.e. people perceive risk as more or less difficult depending on the way in which they see the world (e.g. whether they are fatalists, egalitarians etc.).

This complex series of issues which influence the perception of risk must therefore be taken into account in order to develop an effective means of communicating that risk. The key is in the risk – benefit communication which enables people to make an informed choice regarding exposure to a particular hazard. Risk communication should not be seen as top down (i.e. expert to public) but as a constructive dialogue between all parties.

A6.5.4 The media

The media also play an important role in the public perception of risk. This is because the media are likely to influence judgements about risk much more than people's objective assessment of the 'facts'. The media may or may not directly influence what someone thinks, but the amount of coverage given to an issue can make issues appear significant/important. Social amplification of risks may also occur when an event associated with a hazard interacts with the psychological, social and cultural make up of people, raising (or reducing) the perception of risk and affecting how people then behave. Some researchers have noticed that in some cases, increased coverage actually leads to an increase in factual information (and thus people's ability to make "proper" risk judgements). Conversely, the use of headlines and photographs together with the emotional tone of the article can disproportionately affect the perception of the hazard.

A6.5.5 Trust

The success or otherwise of communications regarding risk involves the consideration of both:

- the message about the hazard itself (its likelihood, potential costs and benefits in mitigation);
- the trust people have in those giving the message.

Failure in risk communication is usually caused by public distrust in both the makers of policy, and officers of companies/regulatory bodies, due to problems of credibility. [“They would say that wouldn’t they”.] Experts presenting technical numerical information about risk which discounts the public perception of that risk as ‘irrational’ become distrusted by the public who view them as arrogant and lackeys of vested interests. It is important to recognise that it is much easier to lose someone’s trust than to build it. Once trust is lost, it is very difficult to regain. The key elements in trust are the competence/credibility of the people putting the argument. People’s perception of such a level of trust is often significantly influenced by the track record of the organisation/expert. For example, that over the last 50 years or so, there has been a general decline in the trust of scientists due to matters such as DDT, thalidomide, Three Mile Island, Chernobyl, BSE etc.

However, the potential hazards associated with contaminated land and their associated risks can also be used by objectors to particular schemes/projects. Such groups of people also have a vested interest, often summarised as “not in my backyard”. Land contamination and the potential risks to people’s health (often the new residents who will live in the proposed new housing development) can be cited by objectors as one of the elements in their opposition to a proposed development scheme.

Experience has shown that to those involved in the assessment/redevelopment of contaminated land, importance must be attached to both the technical assessment of risk and also to the concerns of all stakeholders and their perceptions.

A6.6 Conclusions

- Risk assessment is not just a scientific calculation. Perception is and must be the reality.
- All parties must get it right at the beginning (i.e. both the assessment of risk and the communication strategy).
- Stakeholder concerns are “real” – their perceived risks cannot just be discounted on the basis of some “scientific” judgement.
- It is important that all professional parties are credible and trustworthy.
- These parties must be able to properly communicate the risks that face people and the environment to all of the stakeholders involved.

A6.7 Further reading

- Dialogue for Sustainability [Training Manual]. Environment Council, 2002.
- Guidelines for environmental risk assessment and management. DEFRA, 2000.
- Communicating understanding of contaminated land. Sniffer, 1999.
- Risk communication, a guide to regulatory practice. Ilgra, 1998.
- Risk: Analysis, perception and management. Royal Society, 1992.
- Risk and modern society. Lofstedt and Frewer, 1991.
- Risk communication. Brownfield Briefing, December 2006.

Annex 7

Waste management

A7.1 Waste management framework

A7.1.1 Background

“Waste” is defined in Article 1 (a) of the Waste Framework Directive (Ref 1) as “any substance or object...which the holder discards to intends or is required to discard”. It is the responsibility of the producer of a substance or object to decide whether or not they are handling “waste”. The definition of “waste” is important. If a material is considered waste, then the producer/developer/designer must consider its waste management licensing requirements. Any such requirements are likely to have a significant impact on the design of the earthworks/construction both in terms of time and cost. Furthermore, failure to comply with waste management legislation can result in prosecution. This Annex describes the regulatory requirements and summarises the guidance available for the different options and scenarios often encountered in brownfield re-development.

A number of elements of U.K. policy and guidance with respect to waste are currently at a draft or interim stage. In particular, in 2006 the Environment Agency published a guide to those involved in construction (including remediation) on greenfield and brownfield sites to assist in the determination of whether or not “waste” is being handled, and any associated legal obligations (Ref 2). In addition, a proposed Code of Practice [CoP] (Ref 3) is currently in draft form and is subject to public consultation. The Environment Agency proposes to issues new guidance following any adoption of any Final CoP. It is the intention of the NHBC and the authors to update this Annex once the CoP and any associated Environment Agency guidance is published.

This Annex has reported the current position and has not anticipated any particular outcome. Accordingly, practitioners are advised to determine whether final version of guidance etc. is available and also to consult with the relevant Environment Agency waste officer at the earliest opportunity.

A7.1.2 Regulatory framework and guidance

The following regulations apply to the management of waste with respect to soils arising from construction and contaminated sites:

- Waste Framework Directive (Ref 1);
- Hazardous Waste Directive (Ref 4).

The Waste Framework Directive (Ref 1) sets out a number of definitions including terms such as ‘waste’, ‘recovery’ and ‘disposal’. The Hazardous Waste Directive (Ref 4) provides a precise and uniform European-wide definition of Hazardous Waste with the objective of ensuring correct management and regulation of such waste. The Revised European Waste Catalogue (Ref 5) is a catalogue of all wastes, grouped according to generic industry, process or waste type.

The following UK legislation implements these European Directives and are particularly relevant to brownfield redevelopment and spoil arisings. [See the Reference list to this Annex for the full titles.]:

- The Environmental Protection Act 1990 (Ref 6);
- The Control of Pollution Act 1989 (Ref 7);
- The Waste Management Licensing Regulations 1994 (Ref 8);
- The Controlled Waste Regulations 1991 (Ref 9);
- The Hazardous Waste Regulations 2005 (Ref 10);
- The List of Waste Regulations 2005 (Ref 11).

From 6th April 2008, the Environmental Permitting Regulations (Ref 12) came into force. Environmental Permits replace the system of waste management licensing in Part II of the

Environmental Protection Act (Ref 6) and bring together the Waste Management Licensing Regulations 1994 and the Pollution Prevention Control (England and Wales) Regulations 2000 into one streamlined regime.

A7.1.3 Site waste management plans

The Site Waste Management Plans Regulations 2008 were introduced in England in April 2008 and are likely to follow in Wales). The aims of these Site Waste Management Plans (SWMPs) are; to reduce the amount of waste produced on construction sites and to help prevent fly tipping (Ref 13). Site Waste Management Plans must detail the amount and type of waste that a construction or demolition site will produce and describe how it will be reused, recycled or disposed of. The plan is then up-dated during the construction process to record how the waste is managed and to confirm the disposal of any materials that cannot be reused or recycled.

In Scotland and Northern Ireland SWMPs are not yet proposed as a legal requirement. However some companies and local authorities are requiring their contractors to implement SWMPs to demonstrate commitment to sustainability.

SWMPs are required for any construction project costing more than £300,000. They require all those responsible for projects to forecast how much of each type of waste they will produce and to record how much of it will be re-used or recycled.

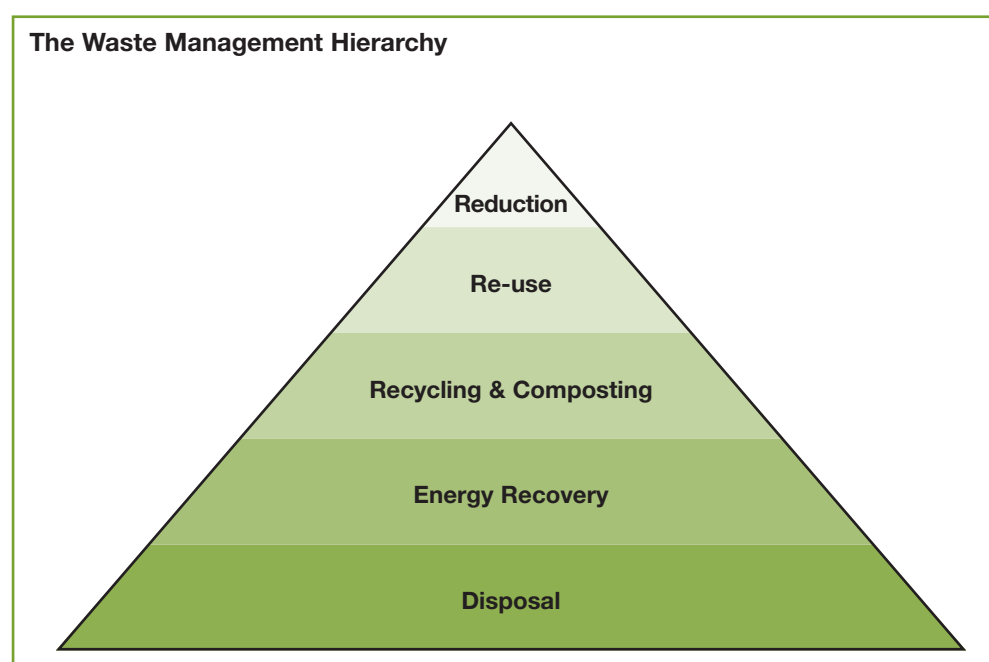
A7.2 Re-use of materials on-site

A7.2.1 General

The waste management hierarchy informs decisions on the management of waste including soils arising from construction work on development sites (Ref 14). The overall aim of the policy is to move activity higher up the hierarchy, reflecting higher levels of sustainable resource and waste management.

The definition of waste and its application to site-won materials is key to determining licensing requirements and potential re-use options, as discussed below.

The Environment Agency's protocol on the re-use of site-won materials is outlined below.



A7.2.2 Uncontaminated soils

Aggregate materials produced from inert waste (i.e. crushed concrete, building materials etc.) in accordance with the WRAP quality protocol (Ref 15) should not be classified as waste and therefore can be re-used on-site without an Environmental Permit (previously waste management licence).

Early discussions with the local Environment Agency waste officer and contractor are recommended for all projects where significant programmes of earthworks are proposed to discuss the potential and requirements for re-use of uncontaminated soils on-site. Further guidance regarding the re-use of uncontaminated soils is planned to be issued by the Environment Agency following publication of any finally agreed CoP.

A7.2.3 Contaminated soils

The current Environment Agency policy is that contaminated soils become “waste” once excavated and therefore an Environmental Permit (previously waste management licence) is normally required to cover their treatment and/or redeposit.

Early discussions with the local Environment Agency waste officer and contractor are recommended for all projects where significant programmes of earthworks are proposed to discuss the potential and requirements for re-use of contaminated soils on-site. Further guidance regarding the re-use of contaminated soils is planned to be issued by the Environment Agency following publication of any finally agreed CoP.

A7.2.4 Waste management license exemptions

Where soils are regarded as “waste” by the Environment Agency, their re-use on-site may take place under an “exemption” from Environmental Permitting (waste management licensing). In order for an activity to qualify for an exemption, the re-use must be carried out:

- Without endangering human health or the environment;
- Without risk to air, soil, plants or animals;
- Without causing nuisance through noise and odours; and
- Without adversely affecting the countryside or sites of special scientific interest.

Exemptions are granted under the Environmental Permitting Regulations (Ref 12) [previously Schedule 3 of the Waste Management Licensing Regulations (Ref 16)]. Further guidance is available at www.environment-agency.gov.uk/commondata/acrobat/exemption_changes_2008963.pdf

In general the following paragraphs are applicable to construction on contaminated land:

- Paragraph 9 – Land Reclamation;
- Paragraph 13 – Manufacture of construction and soil materials;
- Paragraph 19 – Storage and use of waste for construction; and
- Paragraph 24 – Storage of bricks, tiles or concrete (crushing and treatment was previously covered under WML but this is now covered by the Part B authorisation).

Exemptions are often subject to conditions which describe the type and quantity of material to be processed, the methods of disposal or recovery and pollution control measures. If the soil arisings remain classified as Hazardous Waste, exemption will not be granted.

Most exemptions with respect to contaminated land/construction sites are granted with respect to paragraphs 9 and 19. These exemptions restrict the volumes of soils being used (paragraph 9 stating this applies where volumes do not exceed 20,000m³ per hectare). Both exemptions require input from the planning authorities. This may comprise specific planning permission, a note to say the existing planning conditions are suitable for the exemption application or a note to say no planning permission is needed. The Environment Agency will not grant an exemption without such written confirmation from the local authority.

Exemptions cost approximately £500-600 (administration fees) and the Environment Agency recommend that a period of 35 days is allowed for in order to gain an exemption. The Environment Agency will either send a confirmation of the exemption or notification of refusal. There is no appeal process.

A7.3 Off-site disposal

A7.3.1 General

For soils requiring off-site disposal (or on-site re-use if the soils are classified as “waste”), classification into one of the three waste categories is required [Hazardous; Non-Hazardous; Inert]. Chemical analytical data (soil and leachate) must be assessed with reference to the:

1. Framework for Classification (Ref17) [Note: It is understood that the Environment Agency plans to withdraw this document]; and
2. Technical Guidance WM2 (Ref18).

In addition, analysis for Waste Acceptance Criteria (WAC) must be carried out related specifically to landfill acceptance (Ref 19).

A7.3.2 Waste classification

Many practitioners have developed a waste classification spreadsheet that uses the threshold values and approaches described in the references above. The concentrations of contaminants are compared against these thresholds for fourteen different hazards (H1 to H14). Examples of the hazards include H14 – Ecotoxicity, H8 – Corrosivity, H10 – Toxicity for Reproduction etc. The majority of these hazards require assessment of more than one risk phrase. Many risk phrases are associated with more than one contaminant type. For example, R36-38 requires the assessment of data with respect to Xylene, dimercury dichloride, calcium sulphate and copper sulphate.

A7.3.3 Hydrocarbon contaminated soils

Where soils have been initially classified as Hazardous due to elevated concentrations of hydrocarbons, the type of hydrocarbon contamination should be determined. Different threshold concentrations can be applied to certain types of hydrocarbon contamination. Soils that would be categorised as Hazardous using the standard (0.1%) threshold may be suitable for disposal at a Non-Hazardous landfill if the type of hydrocarbon contamination is known (e.g. Diesel has a threshold of 1%). Consideration of certain PAH concentrations is also required. Guidance on the classification of oily waste was published by the Environment Agency in 2007 (Ref 20).

A7.3.4 Other contaminated soils

The results of the waste classification assessment can be used to determine the following:

- whether the soils represent a hazard to the environment and their potential for re-use on-site; and
- whether soils destined for disposal off-site would be disposed of at a Hazardous or Non-Hazardous/Inert Waste disposal facility.

The conservative assumption in WM2 is that all contaminants are present in their most hazardous form (e.g. all arsenic is assumed to be present as arsenic trioxide etc.). Made Ground is commonly classified as Hazardous due to potential ecotoxic effects (H14) by virtue of elevated concentrations of heavy metals (most commonly arsenic, lead, nickel and zinc). However, it is not possible to undertake speciation of inorganic determinands (i.e. determine whether arsenic is present as arsenic trioxide, or more common form such as arsenic pyrite) using standard laboratories. In order to examine this further consideration should be given to the data which could be obtained from leachability analysis and direct toxicity testing.

Leachability data

Soil samples should be scheduled for leachability testing and the results screened against Environmental Quality Standards (EQSs) (Ref 21). If a significant number of samples record exceedences of the EQS for any of the metal determinands (most commonly arsenic, lead, nickel and zinc) responsible for the H14 classification, direct toxicity testing should be considered to fully determine whether the soils should be classified as Hazardous.

Direct toxicity testing

The Environment Agency state (Ref 18) that if a 100mg/l WAF leachate (equivalent to a 0.1g/l leachate) produces a toxic effect of >50%, the sample should be classified as Hazardous on the basis of ecotoxic risk. Therefore, if there is a toxic effect of <50%, the sample should not be classified as Hazardous.

Case study

Chemical analysis was carried out on soil samples from a particular site. Concentrations of up to 15000 ppm lead and 2200ppm zinc were recorded indicating initial classification as Hazardous Waste under H14. Leachability data showed a limited number of samples (approx. 5%) exceeded the EQS for lead. Results for the ecotoxicity testing where both daphnia and algae were exposed to leachates from these soil samples indicated the number of daphnia that died as a result of exposure to the leachate was low (<10%) and the amount of growth inhibition for algae was below the laboratory limits of detection (<10 %). On this basis, it may be argued that in accordance with the EA Guidance, despite the high total concentrations of lead, these soils should not be classified as Hazardous on the basis of ecotoxic risk.

Note: It is understood that the Environment Agency are re-drafting WM2 for H14 which may negate the requirement for speciation and may require WAF only where material is soluble.

A7.3.5 Off-site disposal

Both Inert and Hazardous Waste landfill sites are regulated under PPC permits (or Environmental Permits). Non-Hazardous Waste landfills may be managed under the 'traditional' waste management licenses or PPC permits. Waste destined for both Inert and Non-Hazardous Waste landfills must meet specific waste acceptance criteria (WAC) before it can be disposed of. Non-Hazardous Waste landfill sites do not have generic WAC, instead each landfill site retains site specific assessment criteria against which the chemical dataset is screened. This can have implications for the disposal route as is discussed below.

Non-Hazardous – soil disposal

Soils classified as Non-Hazardous may also be considered acceptable at Inert landfill sites, after treatment and provided they comply with the Inert WAC.

Hazardous – soil disposal

Soils that are initially classified as Hazardous (using WM2) may be landfilled at a Non-Hazardous landfill site, after treatment and provided the soils meet the site specific Non-Hazardous landfill WAC. It is recommended that either remediation or earthworks contractors are contacted to discuss treatment options and the potential for such soils to be accepted for Non-Hazardous landfill disposal.

A7.4 Guidance for remediation and waste management**A7.4.1 Treatment or containment**

The Environment Agency currently regard soils requiring treatment or containment to mitigate risks to controlled waters as "waste" in accordance with Government guidance (Ref 8 and Ref 22). Accordingly, if the materials are defined as waste, then treatment or containment requires an Environmental Permit (previously waste management licence).

Early discussions with the local Environment Agency waste officer are recommended for all projects where significant programmes of earthworks are proposed to discuss the potential and

requirements for treatment or containment of contaminated soils on-site. Further guidance regarding the re-use of contaminated soils is planned to be issued by the Environment Agency following publication of any finally agreed CoP.

A7.4.2 Mobile Treatment Licences

The treatment of contaminated soils or groundwater is a licensable activity (Ref 8) with further useful guidance also provided in Ref 23. Where the type of plant used involves mobile plant, a Mobile Treatment Licence (MTL) is used to regulate this activity. Most remediation contractors will retain a MTL for their specific treatment technology. MTLs require a Deployment Form to be in place. This Form is normally prepared by the Contractor and interprets the MTL in terms specific to the site and the planned treatment activity. Most remediation activities can then be governed by these two documents. There are a number of exceptions to this as follows:

- a) Where the remediation is carried out using fixed plant, the waste is Hazardous and the plant has a capacity of more than 10 tonnes per day, regulation is by means of an Environmental Permit (previously PPC permit);
- b) Where the remediation is carried out using fixed plant and the waste is Non-Hazardous, regulation is by means of an Environmental permit (previously waste management site licence);
- c) Where the remediation is carried out using fixed plant, the waste is Non-Hazardous, is being treated by biological or physico-chemical methods prior to disposal and the plant has a capacity of more than 50 tonnes per day, regulation is by means of an Environmental Permit (previously PPC permit).

A7.4.3 Segregation and sorting

Appropriate levels of site investigation to characterise and delineate contamination on-site should be undertaken to reduce the need for movement and/or recovery or disposal of contaminated materials. Segregation of excavated material doesn't fall within scope of a MTL unless it forms an integral part of it and may require separate authorisation.

A7.4.4 Re-deposition

Currently the Environment Agency position is that if the treated soils are waste, deposition will not be allowed without an Environmental Permit (previously waste management licence). Early discussions with the local Environment Agency waste officer and contractor are recommended for all projects where significant programmes of earthworks are proposed to discuss the potential and requirements for re-use of contaminated soils on-site. Further guidance regarding the re-use of contaminated soils is planned to be issued by the Environment Agency following publication of any finally agreed CoP.

A7.4.5 Re-use of material brought onto site (Hub and Cluster/Fixed soil treatment facilities)

Early discussions with the local Environment Agency waste officer and contractor are recommended for all projects where significant programmes of earthworks are proposed to discuss the potential and requirements for re-use of material brought on to site. Further guidance regarding the re-use of soils is planned to be issued by the Environment Agency following publication of any finally agreed CoP.

A7.4.6 Sustainability

The principles of sustainability of the various treatment/disposal options should be considered at an early stage when discussing disposal routes etc. for contaminated soils. To assess the sustainability of any of these options a typical set of qualitative parameters by which the sustainability of various treatment/disposal options might be assessed could include; noise, dust, cost, carbon dioxide emissions, requirements for importation of clean backfill and stress on existing road network (especially if in centre of city). An assessment of these factors should use both qualitative and quantitative data and should help inform decisions regarding the most suitable treatment/disposal option.

A7.4.7 Solidification/stabilisation

Stabilisation is often used to immobilise metal contaminants by adding cement to raise the pH and lock the metals into the treated matrix. Metal contaminant concentrations are not reduced through this process and therefore the treated by-product will often remain classified as Hazardous Waste. Currently this makes the re-use of the treated product on-site only possible if an Environmental Permit (previously waste management licence) is in place.

Early discussions with the local Environment Agency waste officer and contractor are recommended for all projects where solidification/stabilisation is proposed to discuss the potential and requirements for re-use of such soils on-site. Further guidance regarding the re-use of such stabilised soils is planned to be issued by the Environment Agency following publication of any finally agreed CoP.

A7.4.8 Asbestos contaminated soils

Many derelict contaminated sites often have fragments of cement bound asbestos roofing (etc.). Soils containing asbestos are generally automatically considered a Hazardous Waste. The following extract from the Technical Guidance (Ref 18) provides advice on the classification of soils containing asbestos fragments.

Examples B17.2

Asbestos

All forms of asbestos, regardless of the chemical form (e.g. chrysotile, amosite) or physical form (e.g. cement, fibres, dust) are listed as Carc Cat 1: R45 and T: R48/23 in the ASL. All forms of asbestos are regarded as Hazardous Waste, where the asbestos content is greater than the threshold concentration for Carc Cat 1 of >0.1% w/w.

Waste asbestos cement

The Hazardous Waste Directive [Ref 3] relates to hazard and not to risk, the ability of the waste to release free fibres is not relevant for consideration. Waste asbestos cement sheeting typically contains 10-15% asbestos (predominantly chrysotile). Since the limiting concentration for Carc Cat 1 is 0.1% and the waste contains 10-15% asbestos, the waste is therefore Hazardous by carcinogenic (H7).

If asbestos cement sheeting is present in the waste and is separable, the asbestos cement sheeting would be a separate waste to the soil and should be segregated and assessed separately as Hazardous Waste.

The following process should be undertaken where soils containing asbestos have been identified:

1. Estimate how much asbestos cement is present within the soil mass as a percentage.
2. Estimate the total volume of the soil mass.
3. Asbestos identification to positively identify the material and its form.

In the past quantitative analysis of the cement asbestos has been undertaken to determine the percentage of actual asbestos fibres within the cement bound material. This type of analysis is no longer undertaken by most laboratories. Therefore, recent practice has been to estimate the typical content of asbestos type (Ref 24). An extract of Table 1 showing information regarding cement bound asbestos roof cladding is presented overleaf.

4. Using this data, the proportion of asbestos present in asbestos cement should be multiplied by the percentage estimate on the volume of asbestos cement in the soil/stockpile etc.
5. If this value is less than 0.1% of the total soil volume, the soil should not be classified as Hazardous.
6. Should the stockpile be classified as Non-Hazardous Waste due to asbestos concentrations being less than 0.1% it is recommended that any larger fragments of asbestos cement are removed and disposed of separately. This will ensure that the threshold of 0.1% asbestos by volume for the whole material is not breached.

**Extract from HSE MDHS 100. Table 1. Asbestos containing materials in buildings
Cement Products**

Asbestos product	Location/use	Asbestos content and type/date last used	Ease of fibre release and product name
Profiled sheets.	Roofing wall cladding, Permanent shuttering cooling tower elements.	10-15% asbestos (some flexible sheets contain a proportion of cellulose); Crocidolite (1950-1969) and amosite (1945-1960) have been used in the manufacture of asbestos cement, although chrysotile (used until November 1999) is by far the most common type found.	Likely to release increasing levels of fibres if abraded, hand sawn or worked on with power tools. Exposed surfaces and acid conditions will remove cement matrix and concentrate unbound fibres on surface and sheet laps. Cleaning asbestos containing roofs may also release fibres. Asbestos cement, Trafford tile, 'Bigsix'; 'Doublesix'; 'Super six'; 'Twin twelve'; 'Combined sheet'; 'Glen six'; '3" and 6" corrugated'; 'Fort'; 'Monad'; 'Troughsec'; 'Major tile and Canada tile'; 'Panel sheet'; 'Cavity decking'.
Semi-compressed flat sheets and partition board.	Partitioning in farm buildings and infill panels for housing, shuttering in industrial buildings, decorative panels for facings, bath panels, soffits, linings to walls and cleanings, portable buildings. Propagation beds in horticulture, domestic structural uses, fire surrounds, composite panels for fire protection, weather boarding.	As for profiled sheets. Also 10-25% chrysotile and some amosite for asbestos used for fire doors etc. Composite panels contained approx 4% chrysotile or crocidolite.	Release as for profiled sheets. Flat building sheets, partition board, 'Polilite'.
Fully compressed flat sheet used for tiles, slates, board.	As above and where stronger materials are required and as cladding, decking and roof slates (e.g. roller skating rinks, laboratory worktops).	As for profiled sheets.	Release as for profiled sheets. Asbestos containing roofing slate (e.g. 'Eternit'; 'Turners'; 'Speakers'). 'Everite'; 'Turnall'; 'Diamond AC'; 'JM slate'; 'Glasal AC'; 'Emalie'; 'Efex'; 'Colourglaze'; 'Thrutone'; 'Weatherall'.
Pre-formed moulded products and extruded products.	Cable troughs and conduits. Cisterns and tanks. Drains and sewer pressure pipes. Fencing. Flue pipes. Rainwater goods. Roofing components (fascias, soffits etc.). Ventilators and ducts. Weather boarding. Windowsills and boxes, bath panels, draining boards, extraction hoods, copings, promenade tiles etc.	As for profiled sheets.	Release as for profiled sheets. 'Everite'; 'Turnall'; 'Promenade tiles'.

A7.5 References

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Annex 8

Summary of remediation technologies

[Reproduced from R&D66: 2000]

Note: The following text has been reproduced verbatim from R&D66: 2000 with the exception of the cost information which is not included here. This is because this cost data is dated and may not be useful or relevant in today's market. More recent information is available about some techniques as referenced in the main text.

A8.1 Summary of methods available for remedial treatment of contaminated land for housing development

A8.1.1 Non-technical options

Of the non-technical options, the mostly common is to change the site layout. During the review and analysis steps of selecting a remedial strategy it may be appropriate to review the zoning or layout of the development to establish whether less sensitive components of development could be placed in the areas of greatest risk from contamination. For example, where high levels of contaminants are found in areas designated for sensitive uses, but low levels are found in areas designated for hardstanding, it may be possible to revise the layout to ensure that the sensitive uses are relocated to areas of low contamination so that assessment criteria for those uses would not be exceeded. Similarly, if criteria are exceeded for private gardens, the form of development could be changed to replace private gardens with communal gardens, thus removing the risk of exposure to contaminated home-grown produce.

This approach may save on the costs of remedial treatment. It can often prove more sustainable than removal or treatment of contamination to allow the original form of development because it minimises the amount of disturbance and reduces reliance on limited environmental resources such as landfill for the treatment or disposal of the contamination.

Where changing the site layout is not possible, or changes cannot achieve the risk management objectives, consideration may be given to restricting certain activities on the site after completion of the development in order to protect residents and other sensitive receivers. Controls on construction of outbuildings such as sheds and greenhouses may be effective where there is a risk of accumulation of methane and other gases from the ground. Prohibition of excavation for swimming pools or other below-ground structures might be employed to prevent exposure to contaminants at depth in the soil. Such controls might also be necessary where the integrity of a cover system might be breached by excavation. Sometimes, a highly coloured layer is built in to cover systems to warn against breaching them should they be uncovered by excavation.

If changing the form of development cannot mitigate the risks adequately, and the costs of undertaking remedial measures to make the site suitable for housing development are unacceptably high, consideration might be given to developing the entire site for a less sensitive end-use that might not require the same level of remedial treatment. Clearly, this could have planning implications that should be discussed with the local planning authority.

A8.1.2 Technical options

Of the technical solutions, the civil engineering approaches have been the most widely used in past in relation to housing development. In the future it is likely that other methods will find wider applicability. In appropriate circumstances any of them could be applicable to housing developments. Each of the broad categories of remedial technology is briefly described below.

Civil engineering approaches

The Model Procedures identify two principal civil engineering approaches, containment systems and excavation with disposal. The objective of the containment approach is to modify or remove

the potential migration pathways to potential receptors. Containment may be achieved by the use of cover systems and/or barriers.

Cover systems involve the placing of one or more engineered layers of uncontaminated materials over contaminated ground. They may be used to achieve some or all of the following objectives:

- the prevention of contact by acting as a barrier between site users and contaminants;
- the prevention of upward and downward migration of contaminants;
- the ability to sustain vegetation; and
- the improvement of geotechnical properties.

Cover systems are useful where contaminated levels are only marginally above site-specific assessment criteria. In such circumstances, a limited cover thickness of 0.5m is usually sufficient to prevent most, but not necessarily all, contact. If prevention of all contact is required, 1m of cover may be provided. Often, this will incorporate a physical break layer (for example a geotextile) to prevent inadvertent contact with the underlying soils. The design of cover systems must ensure that the protective functions are not impaired when services are installed and repaired. Further details on the design of cover systems is given in the CIRIA report on barriers, liners and cover systems for the containment and control of land contamination. Cover systems are not effective against contaminants that can move laterally through the ground. Such systems are not usually adequate protection in situations where gases are present in the ground or groundwater moves laterally through contaminated material.

In-ground barriers are generally used to prevent the lateral migration of contaminants. Barriers can be created using cement-bentonite slurry trenches or geomembranes. Sometimes, sheet piles are used. They may be used to achieve some or all of the following objectives:

- to isolate contaminants from the surrounding lateral environment;
- to modify local groundwater flow;
- to reduce contact between groundwater and contamination sources.

In-ground barriers are often used in conjunction with cover systems to isolate contaminants from potential receptors. Barriers may not be appropriate in circumstances where they could block natural groundwater flows.

The dwelling structure, consisting of foundations, sub-structure and ground floor, can provide an effective barrier to certain contaminants. The Building Regulations Approved Document C39 lists metals, metal compounds and mineral fibres found in the ground which will lie within building footprint as not requiring any action (in relation to human health) because the building itself is adequate protection.

If suitably designed and installed, in-ground barriers containment methods can be used to isolate organic and inorganic contaminants in soil, groundwater and also to control the migration of gases. In-ground barriers are used to contain contaminants *in situ*, whilst cover systems can be used in both *in situ* and *ex situ* applications, although they cannot prevent lateral migration in either case. The fundamental limitation of barriers and cover systems is that they leave the contamination in place, so maintenance and monitoring are generally necessary to ensure that they remain effective.

Excavation and disposal of contaminated soil and other materials is currently the most commonly used remedial option. Disposal must be to a suitably licensed waste management site, or a site with an appropriate registered exemption from licensing. The Environment Agency has issued guidance on classification of contaminated soil for the purposes of disposal at licensed facilities.²⁵ Where waste is taken off-site, developers and builders should comply with their obligations under the Duty of Care provisions of the Environmental Protection Act³ which require them to accept responsibility for waste. Waste material sent for disposal should only be carried by registered carriers. If it is proposed that excavated material is to be replaced on-site, it may be necessary to obtain a waste management licence, or a registered exemption from licensing. Advice should be sought from the relevant environment agency in relation to this issue.

Following excavation, it may be appropriate to restore site levels by importing of suitable fill. In such circumstances, it may only be necessary to remove contaminated materials to a depth sufficient to accommodate a cover containment system within the planned site levels. In these circumstances it may be appropriate to leave contaminants on-site below the cover layers, provided that there is not an unacceptable risk to human health or the environment. Where contaminants remain within or beneath cover or containment systems there may be a potential risk to the water environment through their leaching into groundwater.

All imported fill should be thoroughly characterised to ensure that no materials are used that may pose unacceptable risks to potential receptors. Consideration should be given to whether the imported material could be classified as a controlled waste and hence subject to waste management licensing legislation. It is generally advisable to consult the appropriate regulatory authorities to establish acceptance criteria for imported material.

Excavation and disposal may be expensive, particularly in areas with a shortage of suitably licensed landfill sites. In addition, there may be practical considerations that limit its applicability. For example contaminants may be located at depths beyond the practical reach of excavation, or beneath unmovable structures.

Development of housing on land contaminated by landfill gas and other soil gases is possible, but generally only in circumstances where passive measures are sufficient to achieve control. Where gas emission rates and concentrations are so high as to require active measures for control, the regulatory authorities may discourage development for housing.

Various guidance is available on civil engineering based methods to control landfill gas and other soil gases, for example the CIRIA Report 149 on protecting development from methane and the BRE Report on construction of new buildings on gas-contaminated land. Guidance on radon in new and existing buildings is given in the BRE report on guidance on protective measures for new dwellings¹¹ and the Department of the Environment householders' guide to radon.

The principal components of passive protection are as follows:

- gas-resistant membrane;
- cavity tray seal to connect damp-proof course to gas-resistant membrane;
- services entries sealed;
- sub floor ventilation;
- cavity ventilation;
- oversite concrete or membrane below sub-floor voids.

Where passive gas control measures are incorporated into housing development it will be necessary to have a high level of confidence in the durability of the controls and in the provision of long-term maintenance.

Clearly, any such measures aimed at providing a low permeability barrier between the source of gas and the interior of the building will be compromised if the occupants are able to breach it, for example by installing pipework or cabling below floor level or constructing cellars or underfloor storage, or bypass it, for example by building an extension.

Biologically based approaches

Biological remedial methods rely on microorganisms to carry out the aerobic or anaerobic treatment of contaminants, either *in situ* and *ex situ*. Some methods are based on providing favourable conditions for microorganisms which are already present in the soil and water, whilst other methods introduce specially cultured microorganisms. The treatment technologies are normally limited to the treatment of organic contaminants, although some techniques are claimed to treat cyanides and alter soil pH values. There are a wide range of biological treatment options available and it is important to confirm that any method being considered is capable of treating the specific contaminants identified at the range of concentrations likely to be present.

Certain *in situ* biological treatment methods may be particularly appropriate for treating organic contaminants in locations that are not easily accessible by other techniques, for example if they

are beneath unmovable structures or at depths beyond conventional excavation techniques. However, some of the biological treatment options may be slow relative to other remedial options, particularly if they are temperature dependent.

Chemically based approaches

These methods make use of chemical processes, either *in situ* or *ex situ*, to reduce the risks from contaminants in the soil or groundwater. This may be achieved by chemical reaction, sorption or by stimulating biodegradation. A wide range of chemical treatment options is available and it is important to confirm that any method being considered is capable of treating the specific contaminants identified within the site and at the range of concentrations likely to be present.

In situ soil flushing techniques may be appropriate for dealing with organic and metallic contaminants in locations that are not easily accessible by other techniques, for example if they are beneath unmovable structures or at depths beyond conventional excavation techniques.

Physically based approaches

These methods use physical processes to remove contaminants from soil and/or groundwater. Some of the *in situ* techniques may be particularly appropriate for dealing with contaminants in locations that are not easily accessible by civil engineering techniques, for example if they are beneath unmovable structures or at depths beyond conventional excavation techniques. They may be used to remediate sites which have already been subject to development. The physical methods considered in the Model Procedures⁴ are briefly discussed below.

Dual phase vacuum extraction and soil vapour extraction are similar *in situ* techniques involving the use of wells and vacuum extraction to remove vapours, or vapours in combination with free-phase liquid contaminants, from the subsurface. The extracted materials are then treated above ground to remove the volatile compounds. The techniques are generally applicable to volatile and semi-volatile liquids in soil and groundwater. They have been successfully used for the remediation of sites contaminated with petroleum hydrocarbons and in some instances may be applied without moving structures or other infrastructure. Hence it may in appropriate circumstances be applied with a minimum of disturbance to sites that have already been developed. Limitations include the smearing of contaminants during dewatering, possible explosion hazards and operation and maintenance costs if long-term treatment is necessary.

Air sparging is an *in situ* technique for the treatment of volatile organic chemicals in groundwater. Air is injected into the contaminated groundwater and volatile liquids are stripped out of both the dissolved and free phase. The contaminated vapours are then collected for further treatment. In some instances the technique may be applied without moving structures or other infrastructure. The effectiveness of air sparging depends upon the local geology and hydrogeology which controls the air flow around the well head. The technique may lead to the wider dispersion of contaminants and the injection of air may cause chemical precipitation, which can affect flows in the aquifer and also encourage the growth of microorganisms. These factors should be considered before adopting this technology.

Soil-washing and physico-chemical washing are closely related *ex situ* techniques that typically combine physical and chemical processes. Soil-washing generally relies on contaminants being concentrated in separable soil fractions, for example contaminants may be bound to the clay fraction whilst the sand fraction may be relatively uncontaminated. If contamination is distributed across all the soil particle sizes, soil-washing is unlikely to be effective. Soil-washing plant are often based on mineral processing technologies and may include the use of many technologies, for example screens, crushers, water sprays, froth flotation tanks, filter presses, water treatment systems etc. During physico-chemical washing the separated soils are treated in a special reactor with a washing liquid, generally an aqueous solution containing chemicals to either dissolve or adsorb the contaminants. The resultant leachate is then separated from the treated solid for further processing. By use of the appropriate combination of technologies, a wide range of organic and inorganic contaminants can be treated.

Solidification and stabilisation

These technologies are used to 'fix' contaminants in soil and thus reduce the risk of harm. The solidification and stabilisation can include mixing the soil with a cementitious material to produce stable solid, or the use of high temperature vitrification processes to produce a glassy product. Both approaches are typically used *ex situ*, although *in situ* techniques have been developed. The presence of organic contaminants may adversely affect cementitious processes, whilst vitrification is applicable to a wider range of contaminants. It is, however highly energy intensive.

Thermal processes

These involve the use of *ex situ* thermal processes to alter either the contaminants in soil, for example by incineration, or by the use of thermal desorption techniques, to volatilise contaminants from the soil so that they can be either treated or burned. Incineration may be used to treat a wide range of organic and inorganic contaminants, but the treated soil is effectively destroyed and the residue subject to the same regulatory control as other incinerator residues. Thermal desorption processes can treat a range of organic and inorganic contaminants, but may have limited applicability in tightly aggregated soils. Careful consideration has to be given to the treatment of the vapours produced during thermal desorption since these may be polluting and can also pose an explosion risk.

A8.2 Technology summaries for remediation of contaminated land

The following technologies for remediation of contaminated land are summarised in this appendix:

- Containment;
- Excavation and disposal;
- *In situ* biological treatment;
- *Ex situ* biological treatment;
- Natural attenuation;
- Physical treatments;
- Chemical treatments;
- Solidification and stabilisation;
- Thermal processes.

A8.2.1 Containment**Introduction**

The objective of containment is to modify or remove the potential migration pathways between the source of contamination and its potential receptors (for example on-site users or groundwater). Cover systems are usually installed as a long-term solution (design life times are measured in decades) and must be carefully integrated with the future use of the site. The exact construction of the system depends on the ground conditions and the nature of the contamination present. There are three main types of containment, namely cover systems, in ground barriers and hydraulic barriers. Reactive walls are a variation on the theme of barriers in which the barrier contains a reactive material (for example a chemical reactant or active microorganisms) which can treat contamination that comes into contact with it. There is little experience in the UK with such systems, however, and they are not considered in detail here.

Cover systems

Cover systems involve the placement of one or more layers of uncontaminated, inert materials over contaminated ground. They can be used to address the following problems:

1. the exposure of on-site users to contaminated soil by skin contact with the disturbed soil surface which may result from activities such as gardening;
2. the upwards movement of contaminants in groundwater or non-aqueous phase liquids following flooding or excessive rainfall;
3. the uptake of contaminants by homegrown vegetables;
4. the upward movement of soil moisture by capillary action following a period of drought;
5. the migration of contaminant vapours and gases;
6. the downward infiltration of rainwater into the contaminated ground.

Examples of cover materials include the following:

1. natural granular soils (such as gravels) are used in capillary breaks and for drainage channels;
2. natural fine soils (such as clays) are used as barriers to upwards or downwards water flow;
3. soils modified by cement or bentonite are used to improve geotechnical properties;
4. wastes such as crushed concrete and fly ash are used as cheaper alternatives to natural soils;
5. synthetic membranes such as geotextiles are used to prevent gas and water migration.

In-ground barriers

The principal functions of in-ground barriers are: to isolate the contaminants from the surrounding environment; and to modify local groundwater flow to modify and reduce the contact between groundwater and the contaminated source. They are often used in combination with cover systems and hydraulic containment to isolate a contaminated site completely from its surroundings (that is macro-encapsulation). Hydraulic containment is often required to reduce the risk of infiltrating rainwater raising the site water table as a result of the interruption of natural drainage pattern. The effectiveness of installed barriers depends on the type of contamination and the local geology and hydrogeology. In-ground barriers can be used to contain groundwater, free phase liquids and gases.

The most commonly used barriers in the UK are based on sheet piling or slurry trenches. Steel sheet piling is an example of a displacement technology where the large sheets of steel are driven or vibrated into the ground with minimal ground disturbance. Vibration methods can emplace sheets to a depth of 30m. The joints between sheets are often grouted to ensure that the barrier is impermeable. Steel sheets are generally resistant to site contaminants, particularly organics, but may require specialist anti-corrosion coatings in low pH soils. Steel sheeting is normally used where structural or mechanical support is also required.

Slurry trench walls are formed by excavating a trench filled with a bentonite-cement slurry (called a “self-hardening” slurry). While the trench is excavated this slurry remains fluid exerting hydrostatic pressure in order to prevent the trench walls collapsing (thereby allowing excavation down to over 40m). After excavation the slurry hardens to the consistency of a “stiff clay” and forms an impermeable barrier wall with maximum permeabilities in the order of 10^{-9} m/s. A synthetic liner such as a geotextile may be introduced during wall construction to decrease permeabilities further and/or to improve chemical resistance of the wall.

Hydraulic containment

The objective of hydraulic containment is to modify and/or remove the potential migration pathways between the source of contamination and its potential receptors. Hydraulic containment uses groundwater abstraction and re-injection to manipulate the subsurface hydrology and thereby control the migration of contaminated groundwater or in some cases non-aqueous phase liquids. It does not necessarily involve treatment of soil or groundwater although hydraulic systems may be combined with above-ground water treatment or can be used to treat contaminated soil as an *in situ* treatment delivery system.

Hydraulic measures for containment can be classified according to three main objectives:

1. to achieve the separation or isolation of the contaminants from the site groundwater by lowering the water table;
2. to contain or isolate a contaminant plume. The migration of contaminants from the original source depends on a number of parameters including contaminant type, the groundwater flow regime, and the hydrogeological ground conditions. The size and shape of a plume is usually defined by the “unacceptable” concentration of contaminants found at its boundary;
3. to manipulate the hydraulic regime to control and direct groundwater flow patterns so that contaminant migration is minimised. For example, hydraulic measures may be used to direct groundwater inward rather than outward from a site or to divert contaminated groundwater flow from a sensitive use discharge point.

Most hydraulic measures are implemented using well and pumping systems installed singly or in groups. Where the water table lies close to the surface, drainage trenches may sometimes be used. Three types of well are commonly used: abstraction wells to pumpout groundwater for

controlled discharge or further treatment; injection wells to introduce clean water and treatment reagents; and monitoring wells.

Installation of hydraulic containment measures critically depends on a detailed understanding of local and regional hydrogeology. Therefore a detailed site investigation (both geotechnical and chemical) is an essential prerequisite to installing such a system.

Applications

Containment is generally applicable to a wide range of soil types as well as made ground and sediments. It is also effective for a wide range of contaminants, although under high loading pressures some contaminants such as tars and other non-aqueous phase liquids can be forced through the barrier materials.

Specific technical limitations

The fundamental limitation of containment is that the contamination remains in place. The long-term effectiveness is open to doubt with very little information being available on installed systems. Mechanisms for barrier failure are numerous and include desiccation, cracking of clay layers and inappropriate designs for a specific site.

A8.2.2 Excavation and disposal

Introduction

Excavation and disposal of contaminated soil and other materials are important methods for dealing with contaminated land in the UK. Disposal can take place on or off-site in a suitably licensed repository. The method is versatile and able to deal with a wide range of problems. On-site disposal of contaminated soil is applicable to large sites where the placement of a safe storage facility does not interfere with site use or redevelopment. It allows transport cost savings where a suitable off-site landfill facility is a considerable distance from the site.

Approach

Excavation and disposal usually consist of the following tasks:

1. site preparation. This includes management operations such as implementing site security, emplacing containment measures, obtaining regulatory permits, selecting local haulage routes, and the setting-up of “dirty” and “clean” work areas;
2. excavation operation;
3. materials handling. This stage may include rudimentary measures to ensure segregation of contaminated from un-contaminated materials, dewatering, and/or recycling of materials for re-use (e.g. crushing of site debris);
4. post-treatment validation. Investigation and monitoring to ensure that remedial objectives have been met;
5. off- or on-site disposal. This stage involves identification of an appropriate licensed facility for disposal of the contaminated materials;
6. materials replacement. Where excavation and disposal is associated with site redevelopment it may be necessary to import new material to replace that removed.

Planning of excavation and disposal operations should ensure that the appropriate regulatory permits are obtained. These may include a waste management licence (for on-site disposal), discharge consents for liquid effluents, permission to abstract groundwater, development of site specific health and safety plan, and approvals regarding sensitive receptors (for example protected species).

Applications

Excavation can be effective for all types of ground and all types of contaminant, but is not applicable to contaminated groundwater.

Specific technical limitations

Although excavation and disposal may offer the potential for a “complete” solution to contamination at a particular site this is not always the case. In practice, the complete removal of contaminated material is not possible: contaminants may be located at depths beyond the practical reach of excavation plant or beneath unmovable structures such as buildings or

services. Under the “Duty of Care” regulations in the Environmental Protection Act (1990) the owner/producer of contaminated materials and those who handle it have a legal responsibility to ensure its lawful and safe disposal.

A8.2.3 *In situ* biological treatment

Introduction

There are two main types of *in situ* biological treatment, namely bioventing and bioremediation using groundwater recirculation. Bioventing is an approach for optimising biodegradation in soil through the *in situ* supply of oxygen to indigenous microbial populations. Bioventing systems are the product of process integration, combining features of *in situ* soil vapour extraction with bioremediation. Bioremediation using groundwater recirculation seeks to simulate *in situ* biodegradation of contaminants by the addition of dissolved oxygen (or another oxidant such as hydrogen peroxide) and nutrients to groundwater, which is recirculated through the soil in order to optimise treatment conditions. Treatment may be attempted using indigenous microbial populations or laboratory-prepared inocula. Other chemical additives, such as surfactants, may be added to reduce contaminant toxicity to micro-organisms or to increase contaminant bioavailability.

Bioventing

In bioventing systems, oxygen is supplied to the soil using a combination of the following:

1. injection of air into the contaminated zone with a vacuum extraction gradient towards wells positioned outside the contaminated zone;
2. injection of air into the subsurface outside the contaminated zone with a vacuum extraction gradient towards wells positioned inside the contaminated zone;
3. vacuum extraction of air by wells positioned inside or outside the contaminated zone.

Dissolved nutrients and water may be supplied either by percolation from the surface or via a small network of vertical wells and horizontal galleries. Bioventing occurs in the vadose zone and treatment can be extended by artificially lowering the water table. It has been reported that bioventing has been applied to a depth of over 30m.

Bioventing systems are designed to maximise aerobic degradation. Operating flow rates of air are low to minimise volatilisation, and the potential need for treatment of extracted air may, therefore, be lower than for soil vapour extraction systems. The optimum balance between biodegradation and volatilisation depends on contaminant type, site conditions and the time available for treatment. However, facilities for treating extracted air are often still required. This usually includes an air/water separator and an air treatment system such as activated carbon, biofilters, or catalytic oxidation.

***In situ* biotreatment using groundwater recirculation**

In situ biotreatment systems aim to supply oxygen to the soil in aqueous solution in one of the following ways:

1. abstraction and re-injection of groundwater to achieve circulation through contaminated soil. The groundwater is treated in above-ground effluent treatment plant where nutrients and oxygen (or oxygen “carrying” chemicals such as hydrogen peroxide) are added. This process is commonly known as pump and treat;
2. addition of nutrients and oxygen (or chemicals such as hydrogen peroxide) by slow infiltration into the soil surface via a network of vertical wells and/or horizontal galleries in the contaminated soil zone;
3. using an engineered auger system for mixing shallow layers of contaminated soils and for the injection of aqueous solutions of nutrients and oxygen.

To prevent the further dispersion of contamination and the migration of process chemicals (such as surfactants or inorganic nutrients) during treatment, isolation of the contaminated zone is often achieved using either hydraulic or containment barrier methods.

In situ treatment can also be carried out by tilling and ploughing the contaminated soil in a method similar to landfarming where the contamination is confined to a near surface shallow layer.

Applications

Bioventing can be used to treat sands and silts, as well as made ground, sediments and groundwater. It is effective against a range of organic contaminants. Bioremediation using groundwater recirculation has similar applications, but is less effective in made ground.

Specific technical limitations

Bioventing offers advantages over *in situ* bioremediation using aqueous delivery systems because the concentrations of air achievable in the subsurface can be much higher than in systems relying on water as a carrier. However, the effectiveness of bioventing systems is limited by the moisture content in the vadose zone. A saturated soil zone will require that the water level be reduced before bioventing can be carried out.

Significant questions have been raised over the accessibility and availability of subsurface contaminants to *in situ* systems. Bioventing and nutrient addition, usually as an aqueous solution, are in competition for available soil pore space and, therefore, may be mutually antagonistic.

Limitations of groundwater recirculation derive from the delivery systems used to supply nutrients and oxygen to the biologically active zone. Pump and treat systems are limited by factors such as soil heterogeneity, which makes prediction of contaminant migration difficult on even a macro scale for many sites. A reported rule of thumb is that, for successful applications, subsurface hydraulic permeabilities must be greater than 10⁻² m/s. Water is a poor carrier of oxygen and treatment is often limited by lack of oxygen due to this. In using hydrogen peroxide, the oxygen carried increases but the presence of iron and manganese and other catalytic surfaces in the subsurface environment promotes hydrogen peroxide decomposition.

A8.2.4 Ex situ biological treatment**Introduction**

There are four main types of *ex situ* biological treatment. In biopiles, biological degradation of contaminants is achieved by optimising conditions within a soil bed or heap. The critical element in this process is aeration. 'Landfarming' uses a treatment-bed approach in which biological degradation of contaminants is achieved by optimising conditions within a ploughed and tilled layer. Windrow turning is an *ex situ* biological treatment process using raised treatment beds and waste composting technology. Biological degradation of contaminants is achieved by optimising conditions within a raised soil bank ("windrow") amended with bulking agents to improve structure and aeration. Slurry-phase biotreatment uses a bioreactor for accelerating the biodegradation of soil contaminants. Excavated soil is slurried with water and mixed with degrading organisms, air, and nutrients in one or more reactors. After treatment the slurry is dewatered; the process water may be treated to remove organic and inorganic contaminants and is commonly recycled.

Treatment may often include the use of amendments such as sewage sludge or other organic wastes, such as vegetation, to provide structure, nutrients, and additional microbial degraders.

Biopiles

Treatment using biopiling involves excavating and stockpiling contaminated soil, commonly on an impermeable base. The base is required to prevent uncontrolled runoff of any leachates that form during the bioremediation process. Analysis of the leachates may be used to monitor nutrient or contaminant concentrations, as a mechanism to ensure consistent and favourable conditions are maintained. A network of support piping may be installed to provide a route for introducing nutrients, moisture, and aeration, depending on the level of sophistication required for the engineered heap. The network of piping may be installed at the base of the heap, within the heap, or on the surface of the heap depending on its function, for example at the base for air extraction and on the surface for irrigation. Biopiles have been built as high as 4 m although adequate aeration and possibly process temperature control is more difficult with increasing pile height. Volatile and gaseous emissions can be controlled by collection through use of a heap enclosure (for example portable greenhouses) or more commonly by drawing air through the system. Contaminant emissions can be removed from the drawn air using a biofilter or by adsorption onto activated carbon. Biodegradation is usually carried out using biostimulation of indigenous microbial communities but introduced organisms have also been used.

The rate of biological processes is temperature dependent and seasonal variations may affect the rate of degradation. Temperature can be controlled by enclosing the pile in a greenhouse-type structure or by heating the air/water entering the pile.

Landfarming

Landfarming was first used for the treatment of refinery wastes from the petroleum industry. A range of landfarming methods exists, ranging from simple to complex techniques. It can be carried out on-site or at a fixed off-site facility. Typically excavated contaminated soil is spread over a cleared and prepared area to a thickness of about 0.5m. To protect the underlying soil, a liner is sometimes used to contain leachates which may form during treatment; however, this type of containment means that cultivation must be carried out carefully. In more advanced and engineered systems, a layer of permeable sand may be placed on top of the liner with a network of drainage channels for leachate collection. An additional role of a sand layer is to protect the liner during the laying of the soil treatment bed so that it may be reused several times. Using standard or slightly modified agricultural techniques, the soil layer is ploughed and tilled to improve soil structure and increase aeration. Aeration is achieved by cultivation. The moisture content can be optimised by adding water at periodic intervals and, if necessary, nutrients.

Several types of landfarming processes cover the soil layer with a modified plastic film greenhouse which both prevents escape of volatile emissions and provides protection from the weather.

Windrow turning

Windrow turning is carried out on-site or at a fixed off-site facility. Excavated contaminated soil is heaped on a cleared and prepared area to a height of 1-2 m. Placed underneath the treatment bed a liner may be used to contain the leachates that may form during treatment. Materials such as wood chips, bark or compost are commonly added to improve drainage and porosity within the heaps and, in some cases, these materials can be microbiologically pretreated as proprietary seeding materials. Drainage galleries may be installed to collect and recycle percolating water and maintain an optimum moisture content within the pile.

Windrows may be mixed (or “turned”) using agricultural machinery or specialised compost manufacturing machinery. Turning enhances biodegradation by improving homogeneity, providing fresh surfaces for microbial attack, assisting drainage, and promoting aeration. Otherwise, aeration in the process is passive.

Windrow turning requires significantly more area than *in situ* treatment since the soil is treated above ground, but is likely to require less area than landfarming since bed thickness is considerably greater. Moisture content and temperature are critical process control parameters.

Slurry-phase biotreatment

A generalised example of the process steps of a slurry-phase-based treatment is outlined below:

1. pretreatment of the feedstock to remove rubble, stones, metal objects etc. and produce an optimum particle size range for the slurry process (for example <4mm);
2. mixing of the feedstock with water to create a slurry (typically between 20-50% by weight of soil);
3. mechanical agitation of the slurry in a reactor vessel to keep solids suspended and to optimise contact between contaminants and micro-organisms;
4. addition of inorganic and organic nutrients, oxygen and pH control reagents. Some slurry systems may also use oxidants such as hydrogen peroxide, ozone and UV light as a chemical pretreatment to reduce the primary organic contaminants to more degradable intermediaries;
5. possible addition of microbial organisms either initially to seed the reactor or on a continuous basis to maintain optimal biomass concentration;
6. dewatering of the treated slurry on completion of the treatment, with further treatment of residual aqueous waste streams where appropriate.

Slurry-phase bioremediation can also be carried out on-site in lagoons. In certain cases lagoons may already be present, in which case this treatment could be described as *in situ*. These lagoons often contain hazardous liquid waste in addition to contaminated soil. Lagoon-based systems do not incorporate physical separation as pretreatment. Mixing is carried out using specialist equipment which often includes an aeration and nutrient addition system.

Applications

These methods can be used to treat degradable organics, including PAHs and non-halogenated compounds. They may also be effective for cyanides. They are effective in granular soils, such as sand and silts, but not clays and peats. They can also be used to treat made ground and sediments.

Specific technical limitations

Often biopile processes and landfarming may have a beneficial effect on soil structure and fertility. Windrow turning may also have a beneficial effect, especially if bulking agents are added. However, slurry phase treatments may have a severe adverse effect on soil structure since treatment is often accompanied by some form of physical pretreatment to separate the soil into sized fractions. The use of chemical agents such as hydrogen peroxide may also lead to soil damage, for example through interaction with soil organic matter which either may be destroyed or altered into potentially more toxic forms. It may be possible to overcome these effects during post-treatment where the reconstruction of a fertile soil could be emphasised. Some *ex situ* techniques offer improved process containment over *in situ* approaches, although several USA vendors do not recommend their processes for remediation of VOC-contaminated soils because of concern over atmosphere emissions during treatment. However, the opportunity to use landfarming processes critically depends on the space available since the treatment bed is usually no thicker than 0.5m and, therefore, covers a relatively large area. Where landfarming is used without a liner it has no process containment and contamination of topsoil beneath the treatment bed may occur. In this case the soil base should be monitored for the build-up of heavy metals which may leach out of repeated soil applications.

A8.2.5 Natural attenuation**Introduction**

Naturally occurring processes may act to reduce the concentration and environmental load of a pollutant within soil and aquifer systems. Physical, chemical and biological processes may act on a contaminant to restrict its movement; disperse the contaminant so that its concentration decreases; or degrade the contaminant so that the overall contaminant load declines. The most important processes that are generally included within the umbrella of 'natural attenuation' are biodegradation, retardation, sorption, hydrodynamic dispersion, dilution and volatilisation.

Approach

The potential for the successful application of natural attenuation depends principally on the nature of the pollutant and the hydrogeochemical environment in which it is located. It is most applicable for reactive (degradable) pollutants and pollutants subject to significant retardation, particularly when located in low permeability aquifer systems. Pollutants that are persistent and/or bio-accumulative, or located in highly permeable aquifers which allow rapid groundwater and contaminant plume migration, are less likely to be suitable candidates for a natural attenuation remediation.

Before adopting a natural attenuation strategy, it is fundamentally important that comprehensive site investigation and characterisation is undertaken, and that the processes are shown to be active at a rate will ensure protection of all receptors throughout, and following, the remedial period.

Natural attenuation is not a 'do-nothing' approach. Environmental monitoring of the contaminant plume and aquifer conditions during the remedial operation is likely to be significantly more intensive than would be necessary for other remedial technologies. The principal advantages of natural attenuation are low capital costs associated with treatment plants and relatively low disturbance of surface activities, which may continue undisturbed during the treatment period.

Applications

Natural attenuation can be used for groundwater contaminated by some organic contaminants, heavy metals and some inorganic substances.

Specific technical limitations

The application of natural attenuation has been demonstrated for a range of aliphatic and aromatic hydrocarbons (based on biodegradation) and heavy metals (based on retardation). Although there is increasing evidence to suggest that natural attenuation may also be applicable to chlorinated solvents in some situations, however there is concern over the potential for

degradation of the chlorinated solvents to form more toxic breakdown products. Little information is available on the suitability of this treatment method for other contaminants or the complexities of treating contaminant mixtures.

A8.2.6 Physical treatments

Introduction

There are two main types of physical treatment. The first involves washing of the soil. Soil-washing is an *ex situ* physical treatment involving mechanical and chemical separation of contaminants or contaminated soil particles from uncontaminated soil. Soil-washing systems are often closely related to *ex situ* chemical extraction and leaching processes.

The second type of physical treatment involves extracting of substances from soil in the vapour phase from soil or groundwater. This is achieved either by applying a vacuum to suck the vapour out or by sparging with air to flush it out.

There are three main variants of technologies relying on extraction of contaminants in the vapour phase. Air sparging is an *in situ* approach for the treatment of groundwater contaminated with volatile organic chemicals such as benzene, toluene, ethylbenzene and xylene (BTEX). The principles of air sparging are related to both air stripping (an established waste treatment) and soil vapour extraction (SVE). The process exploits differences between the aqueous solubility and volatility of contaminants to transfer contamination from groundwater to the vapour phase. Soil vapour extraction (SVE) is an *in situ* physical treatment process, which exploits the volatility of certain contaminants to remove them from the soil. A vacuum is applied to wells installed in the ground and the air that emerges is treated to remove the contaminant vapour. Dual-phase vacuum extraction is a variation on SVE in that, in addition to extraction of contaminant vapour in air, any free product (that is a non-aqueous solvent layer floating on top of the groundwater) can also be extracted as a liquid. The liquid and vapour phases may be extracted together or separately.

Soil-washing

Many soil-washing systems and techniques evolved or were adapted from the mineral processing industry, where methods were developed for separating valuable ore minerals from gangue material which does not contain economically extractable minerals. Commercially operated soil-washing systems can be fixed at a central facility or installed on-site. Each configuration of plant design is based on the results of a treatability study that investigates the contaminant distribution within the soil. The principal stages in soil-washing can be identified as follows, although not every step will be used for a site specific treatment scheme:

1. deagglomeration and slurring of soil using water sprays, jets, and low intensity scrubbers. Surfactants may be added to improve suspension of fine particles;
2. high intensity attrition of soil using high pressure water sprays and centrifugal acceleration or vibration can be used to remove surface coatings of contaminants and fine contaminated particles from larger particles such as sand and gravel;
3. sizing and classification of soil to separate soil particles according to size and settling velocity using screens and hydrocyclones. In many instances the coarse soil fractions such as sand and gravel are often less contaminated than finer silts and clays because of their lower surface area and adsorption capacity;
4. further segregation based on differences in density (using jigs, spirals and shaking tables), surface chemistry (using froth flotation), and magnetic susceptibility (using a magnetic separator) may be used to concentrate contaminants into a smaller soil volume or to produce fractions more amenable to specific further treatment;
5. dewatering of all fractions produced by separation, for example, by filtering or flocculation;
6. process water treatment may be necessary if contamination has been mobilised into solution.

Air sparging

A qualitative assessment of the applicability of air sparging to a specific contaminant can be made from its Henry's Constant which is the ratio of its aqueous solubility to its vapour pressure. The basic air sparging system involves the injection of air into the contaminated groundwater from below the water table. As the air bubbles rise to the surface there is a preferential transfer of volatile contaminants from the dissolved or free phase to the vapour phase. The contaminated

vapours are collected at the surface for further treatment by using a series of injection and extraction wells to control subsurface airflow. Above-ground treatments of the collected vapour may include activated carbon filters, biofilters, and condensers.

Soil vapour extraction (SVE)

In the basic SVE design, vertical or horizontal wells are sunk into the contaminated soil. Horizontal wells are used for shallow contamination problems (less than 3m) or where a high water table restricts the depth of vertical wells. A vacuum is applied to a number of these wells to draw air slowly through the contaminated soil, where it is treated above ground by a combination of an air/water separator and an off-gas treatment system such as activated carbon. Although the general direction of airflow can be controlled, for example by placing the extraction wells either inside or outside the contaminated zone, air drawn through the soil will follow the pathway of least resistance. Air drawn through the soil pores carries volatile vapours away by a process known as advection. Contaminants continually vaporise from one or more of the condensed phases (dissolved, free, adsorbed) to maintain equilibrium within the pore space. In soils of lower permeability, the volatile contaminants diffuse to the preferential airflow pathways where advection draws them to the surface.

A8.2.7 Dual-phase vacuum extraction

Dual-phase vacuum extraction is complementary to soil vapour extraction (SVE) and involves the following processes:

1. dewatering of saturated soils to allow enhanced use of SVE technology;
2. recovery of non-aqueous phase liquids (NAPL) and dissolved contaminants. Dewatering is typically carried out in the smear zone at petroleum hydrocarbon release sites where the light non-aqueous phase liquid (LNAPL) contamination can be present as immiscible product or as residual saturation within the capillary zone;
3. control of the upwelling effects caused by application of a vacuum to the soil;
4. increasing groundwater recovery rates.

Free-product removal is an important consideration in a site remediation scheme since (i) it contains a significant proportion of the contaminant mass, (ii) it provides a long-term source and (iii) removal of free-phase can improve groundwater quality considerably. It is imperative therefore that the design of a dual-phase extraction system should be such that the selected ground water clean-up criteria or objectives can be achieved.

Applications

Soil-washing can be used to remove a wide range of organic and inorganic contaminants and heavy metals from many soil types (excluding clay). The other techniques are effective for a range of volatile and semi-volatile organic contaminants in soil and groundwater.

Specific technical limitations

Soil-washing systems depend on a readily exploitable contaminant distribution within the soil to affect remediation. If contamination is widely distributed across soil particles according to size and composition then soil-washing is unlikely to be effective. Economically, soil-washing systems are best applied to treat soils with a silt and clay content below 30-40 percent by weight, since these often represent the most contaminated soil fractions and would therefore incur higher disposal costs. Fine particle sizes also present a materials handling problem. Soil-washing can have a severe effect on soil structure and fertility since it is subjected to slurring, mechanical abrasion and exposure to toxic process chemicals.

The effectiveness of air sparging, dual-phase vacuum extraction and SVE depends on the subsurface geology and hydrogeology which controls both the groundwater and air flow around the well head. Low permeability soils reduce the accessibility of SVE to reach all contamination. At complex sites the heterogeneous nature of the subsurface can make process monitoring and verification of treatment performance difficult.

Air emissions produced at the surface may require above-ground treatment at additional cost, for example by catalytic oxidation. Where vapour concentrations are very high an explosion hazard may exist.

A8.2.8 Chemical treatments

Introduction

A fairly diverse range of chemical treatments is available for contaminated soil. Some are closely related to physical treatments and could be classified as either. Five chemical treatments are considered here. Two of these, namely surface amendment and soil flushing, are *in situ* technologies. Surface amendment covers a range of *in situ* chemical treatments that have been developed for the remediation of surface or shallow depth contamination. They involve adding of process chemicals directly to the soil and are designed to transform and immobilise (and hence stabilise to some degree) a range of organic and inorganic contaminants. Soil flushing is an *in situ* chemical treatment process where soil contaminants are transferred to an aqueous leachant which is recovered from the subsurface and treated by conventional effluent treatment processes.

Three *ex situ* technologies are also considered. These are chemical dehalogenation, solvent extraction and physico-chemical washing. Chemical dehalogenation involves a chemical reaction in which chlorine or fluorine atoms are split off from halogenated molecules. The dehalogenated compounds produced are generally less toxic or harmful than the halogenated species. Solvent extraction is an *ex situ* treatment which involves the transfer of soil contaminants into either an organic or a supercritical fluid (SCF)-based solvent. This solvent is separated from the soil for further processing and/or disposal. Physico-chemical washing is an *ex situ* treatment which typically combines physical and chemical processes and so could be included in either category. It is often considered as simply an enhancement of soil-washing systems. Treatment involves the mobilisation of soil contaminants into a liquid (usually an aqueous solution) which is then separated from the treated solid for further processing.

Surface amendment

Lime addition involves applying of lime to the soil as a powder or in aqueous solution. The lime may be ploughed into the soil surface using conventional agricultural techniques. Liming the soil raises the pH, thereby reducing the bioavailability of many heavy metals through increased soil adsorption.

Organic matter may be added to the soil as manure or sewage sludge to reduce bio-availability of heavy metal contaminants. The material is ploughed into the soil surface using conventional agricultural techniques. Many heavy metals are strongly adsorbed by organic matter and are thereby more firmly held within the soil.

Chemical reduction uses reducing agents such as sodium polythiocarbonate and ferrous sulphate added to contaminated soils as powder or aqueous solution to treat metal contaminants such as chromium. Cr(VI) is a highly toxic and mobile element which can be reduced to an immobile form Cr(III). Organic matter is an important amendment in the reducing process and acidic conditions are also required (pH 4.5-5.5). After treatment, liming raises the pH and precipitates Cr(III) hydroxide.

Soil flushing

Soil flushing can be executed by two mechanisms, depending on depth of contamination. For shallow depths the flushing solution is delivered by infiltration from the soil surface, where it percolates slowly downwards through the contaminated soil. Leachate which has passed through the contaminated area is collected along ditches or horizontal galleries where it is pumped to a surface treatment plant.

For contamination at greater depth, for example within aquifer sediments, a pump and treat system may be used. The flushing solution is injected and abstracted through wells in the contaminated zone. Contaminated solution is pumped back to the surface for surface effluent treatment. The aqueous-based leachants used in soil flushing are generally either inherently more environmentally benign or used at far lower concentrations than for the corresponding *ex situ* methods. After treatment is complete the majority of reagent is recovered above ground for further processing. Typical reagents include the following:

1. acids for heavy metals and "basic" organics such as amines and ethers;
2. alkalis for some metals such as tin and lead, and some phenols;
3. complexing agents for metals;
4. surfactants for non-aqueous contaminants such as mineral oils.

After treatment it may be necessary to return subsurface conditions to environmentally acceptable limits, for example, by adding alkalis to neutralise any excess acid still present.

Chemical dehalogenation

The two variants of chemical dehalogenation are as follows:

1. chemical system which uses specific proprietary agents to achieve dehalogenation in a reactor system operating at temperatures up to 180°C;
2. thermal and chemical system which uses elevated temperatures (above 850°C) and reducing conditions to achieve thermal reduction of halogenated contaminants.

An example of a chemical system is the APEG process which uses an alkoxide compound to react with chlorinated hydrocarbon contaminants to form a glycol ether and an alkali metal salt. The alkoxide is commonly formed by reacting an alkali metal hydroxide (usually potassium) with an alcohol or glycol, such as PEG 400. Dechlorination may proceed to completion, although replacement of a single chlorine is sufficient to make the reaction products water soluble. The basic treatment process can be divided into several stages: soil preparation; soil and reagent mixing; soil and reagent separation; and soil post-treatment.

Soil preparation includes screening in order to remove coarse debris which can damage the reactor. The soil and reagents are combined in a chemical reactor to optimise reagent-contaminant contact. Typical conditions include heating the soil slurry to between 100-180°C and mixing for up to five hours per batch. After the reaction is complete excess reagent is separated from the soil, which is then further treated in order to neutralise the effect of any entrained chemical, for example by the addition of acid.

Thermal dehalogenation processes operate at temperatures greater than 850°C and involve gas-phase reduction of halogenated compounds in a hydrogen atmosphere. Chlorinated hydrocarbons, such as PCBs and dioxins, are reduced to methane and hydrogen chloride in the combustion chamber. Soil and sediment are usually pretreated in a thermal desorption unit to volatilise contaminants which are carried into the reduction chamber by a stream of recirculated gas.

Solvent extraction

Solvent extraction differs from physico-chemical washing since a non-aqueous solvent is used. A typical process consists of three distinct stages: physical pretreatment of the soil; extraction with solvent; and separation and recovery of the solvent.

Soil preparation may include excavation and screening to remove coarse debris. Depending upon the specific process the soil may be slurried with the solvent prior to extraction. In the chemical extractor the soil and solvent are mixed to optimise intimate contact. The reported effectiveness of this technology depends not on the chemical equilibrium between the solvent and the soil but on the rate of transfer of contaminants from the soil surfaces into solution. The extracted organics are removed from the extractor vessel with the solvent and are passed to a separator, where the pressure or temperature is changed, thereby causing the organic contaminants to separate from the solvent. The solvent is recycled to the extractor and the concentrated contaminants are collected for further treatment, recycling, or disposal. The cleaned soil is filtered and dried for reuse or disposal. Vapours produced from the drying stage may be condensed and recycled or treated by effluent control.

In SCF-based systems, liquefied gases such as propane, butane, and carbon dioxide are used as solvents for separating organic contaminants from soils and sediments. In these systems the temperature and pressure of the solvent is maintained close to its critical point where the gas behaves as a liquid. However, the solvent's viscosity and diffusivity are intermediate between a liquid and gas, thereby enabling it to mix intimately with the contaminated soil. Overall, treatment schemes are similar to those for solvent extraction except that the temperature and pressure in the mixing vessel are elevated.

Physico-chemical washing

In physico-chemical washing, excavated soil is slurried with water, classified and separated into different soil fractions by a soil-washing plant. Where integrated with a chemical leaching stage,

separated soil fractions are usually treated in a special chemical vessel or reactor. This is distinct from the use of small quantities of process chemicals, such as surfactants and pH modifiers, which may be used in a soil-washing plant without chemical leaching.

Leachants which are used in commercial systems include: acids and alkalis; surfactants; and chelating agents. Systems developed in the UK include the following:

1. combination of oxidising agent, pH moderator, and chelating agent is used to enhance contaminant solubility;
2. fine-grained particles of exchange resin are mixed into the soil slurry to adsorb contaminants. Resin and soil are separated physically (by size or density) after treatment.

Leaching may be carried out using a series or cascade of stirred chemical reactors which can be either counter-current (flow of leachant opposes slurried flow) or co-current (flow of leachant and slurried soil in same direction). The flow rate is carefully controlled to optimise the residence time for soil and leachant contact. After contact, treated soil and leachate are separated by processes including filtration. Leachate is treated by an effluent treatment system and, where possible, recycled. Treated soil is dried and ready for further use or safe disposal.

Applications

The *in situ* technologies are effective for sandy, silty and peaty soils and sediments. Surface amendment can be effective in changing the chemistry of inorganic substances, while soil flushing is applicable to organic contaminants.

Of the *ex situ* techniques, dehalogenation can treat a range of halogenated substances, including dioxins. Solvent extraction can be used to remove organic substances, while physico-chemical washing will also remove inorganic substances. Like the *in situ* techniques, adequate penetration and mixing of the reactant or solvent with the soil is necessary. Some types of material, such as made ground, may not be easily treatable.

Specific technical limitations

Chemical treatments are generally costly and require considerable energy and chemical reagent inputs. *In situ* systems require a thorough understanding of ground conditions and moderate to high soil permeability.

Some chemicals are reactive with or do not mix with water and other soil components. Where this is an issue, the soil may need to be dried first, thereby adding to the cost of treatment. Some treatments also prevent the reuse of the treated material as soil, because they damage its structure.

With simple amendments the contaminants are not removed from the soil and, therefore, remediation assessed against guideline values expressed as total soil concentration of contaminants will show no effect. The use of soil amendments is a temporary effect and will require repeated applications to ensure that pH and soil organic matter content stay within appropriate limits.

A8.2.9 Solidification and stabilisation

Introduction

Two systems are considered here. The first involves cement and pozzolan-based systems. The selection of suitable binding agents for a specific mixture of contaminants and soil type is applied following a laboratory study. In general, this involves mixing a sample of the soil with a large number of different binders and binder ratios and investigating which mixes perform best in physical tests, such as compressive strength or hydraulic permeability, and chemical tests, such as leachability. Binder additives include Portland cement, fly ash, soluble silicates, organophilic clays, and lime.

The second system involves vitrification. This is typically used *ex situ*, although it has also been demonstrated as an *in situ* approach. It may also be considered as a thermal treatment. Vitrification involves the application of heat to melt contaminated soils to form a glassy product. The high temperatures associated with vitrification result in the combustion of organic contaminants whilst inorganic contaminants, such as heavy metals, are immobilised within the glassy matrix.

Cement and pozzolan-based systems

In situ cement and pozzolan-based approaches involve the use of soil mixing equipment. An example of a soil mixing system which has been developed in the USA and Japan comprises one set of cutting blades and two sets of mixing blades attached to a vertical auger. The auger is lowered into the soil where the rotating blades cut and mix the soil around them. Solidification and stabilisation agents and water can be injected into the mixing zone. Vertical columns of solidified soil are produced as the blade advances into the ground to the maximum depth, and are remixed as the equipment is withdrawn. By carefully controlling where each column is emplaced, the area of contaminated soil can be covered by a network of overlapping columns.

Ex situ treatment can be applied in several ways. The first option is plant processing, in which contaminated soil is excavated and mixed with solidifying and stabilising agents in a specifically designed plant or in plant adapted from other applications such as concrete mixing. A second approach is direct mixing, in which excavated material is transported to a dedicated area of the site where it is spread out in layers and the solidifying agents added using mechanical equipment.

Direct addition and mixing may also be used to treat contaminated sludges and sediments present in lagoon areas and ponds. A third approach is in-drum processing which involves excavation of contaminated soil into drums or other types of container. Solidification and stabilising agents can be added directly to the drums which are mixed using specialist equipment and allowed to set.

Vitrification

An *ex situ* vitrification system consists of a melter, heat recovery system, air emissions control system, and a storage and handling area for feedstock. Many of the commercially available systems are modified from the manufacture of glass. Heat can be delivered by using plasma arcs, hot gases or carbon electrodes.

A UK vitrification system uses a “hot-top” glass-making furnace operating at temperatures of up to 1,500°C for a period of approximately 10 hours. The feed material consists of contaminated soil (up to 50 percent by weight) and glass-making additives such as lime, alumina, sand and cullet (recycled waste glass). The molten glass is discharged from the furnace along a conveyor belt where it undergoes rapid cooling. Off-gases produced during vitrification are cooled from 1,500°C to 770°C by a series of heat exchangers, scrubbed to remove particulates, VOCs, and acid gases, and discharged to the atmosphere.

A US system uses arc plasma heat to detoxify contaminants present in the feed material at temperatures from 1,540°C to 1,650°C. Off-gases from the vitrification chamber are passed to a secondary combustion chamber where they are heated to up to 1,370°C to destroy residual organics.

Applications

These technologies are applicable to a wide range of non-volatile organic and inorganic contaminants and heavy metals in a range of soils and sediments. Cement and pozzolan systems do not work well with peat and made ground, however.

Specific technical limitations

These systems may have difficulty with soils containing either a high level of organics (greater than 5-10 per cent) Low levels of extremely hazardous organics may also be problematic in cement and pozzolan systems. High levels of some substances affect the setting mechanism in each case and must therefore be checked.

A8.2.10 Thermal processes

Introduction

Two technologies are described here. Incineration is an *ex situ* thermal technique which uses high temperatures (800-2,500°C) to destroy contaminants by thermal oxidation. Thermal desorption is an *ex situ* technique which involves two processes: (1) transfer of contaminants from soil to vapour phase via volatilisation; and (2) treatment of off-gases from the first process to either concentrate contaminants, for example by condensation of metal vapours, or destroy them at higher operating temperatures, for example combustion by incineration.

Incineration

A typical incineration system consists of pretreatment, a one or two-step combustion chamber, and post-treatment for solids and gases. The highest temperatures occur within incinerator systems equipped with a secondary combustion chamber for off-gas burning. A key factor in incineration is the length of time the soil remains at the high temperatures within the reactor (the residence time). Depending on the type of combustion chamber used, the maximum particle size which may be treated ranges from 0.3-0.025 m in diameter.

Operating temperatures for transfer of contaminants depend on soil type and the physical properties of the contaminant present. Commonly used temperatures to volatilise organics are in the range up to 600°C and for mercury from 600-800°C.

Thermal desorption

Desorption units can be categorised according to the heating system used, although many commercially available systems use a combination of these methods. Direct heating uses hot air or open flame (for example in a rotary kiln). Indirectly heated systems transfer heat through contact across a metal surface which is usually heated by electricity or a hot fluid such as steam (for example using a rotary screw conveyor).

Post-treatment of off-gases depends on plant-specific factors but may include: combustion at high temperatures (up to 1,400°C) in an after burner followed by gas cleaning and discharge; thermal destruction at moderate temperatures (200-400°C) using catalysts; and conventional gas scrubbers and carbon adsorption.

Applications

Incineration is effective for a wide range of contaminants in all types of soil, including made ground. However, it does not destroy heavy metals and some other inorganic substances, most of which will remain in the ash.

Thermal desorption can be used to remove a range of organics, heavy metals and cyanide from most soils (except peat). In the USA thermal desorption units are often used for small-scale remediation of petroleum spills and may therefore require less space for operation than an incineration unit.

Specific technical limitations

During soil combustion the volatilisation of metals at high temperatures requires expensive off-gas treatment and the generation of alkali metals, chlorides and fluorides can lead to damage to the kiln wall. Careful control of the feed material is required to ensure that system blockages and insufficient heating do not occur. Concern over the use and sustainability of incinerators for hazardous waste treatment have been raised in the UK and the USA.

Incineration systems require considerable energy inputs and are particularly susceptible to fluctuations in cost associated with variable moisture content. Soils treated by incineration are essentially destroyed and must be disposed of according to the waste management regulations applying to treatment residues. At the lower operating temperatures of a desorption unit (100-180°C) the physical structure of the treated soil may be maintained, although organic matter can be oxidised. At higher temperatures the treated residue may no longer resemble a soil at all, but some projects report that soil function may potentially be restored through careful husbandry.

There are several specific operational limitations reported for thermal desorption systems. Tightly aggregated soils, for example, clay-rich clods, reduce system performance because material at the centres of these clods are often cooler than at the surfaces. Unless emission controls have been specifically set up to deal with mixed contaminants, the presence of volatile metals at the applied temperatures can cause pollution control problems. The presence of significant amounts of soil organic matter (greater than 5-10 percent) may be a problem, since the concentration of contaminants within the reactor atmosphere must be below the explosion limit. Soils with a high pH may corrode internal systems.

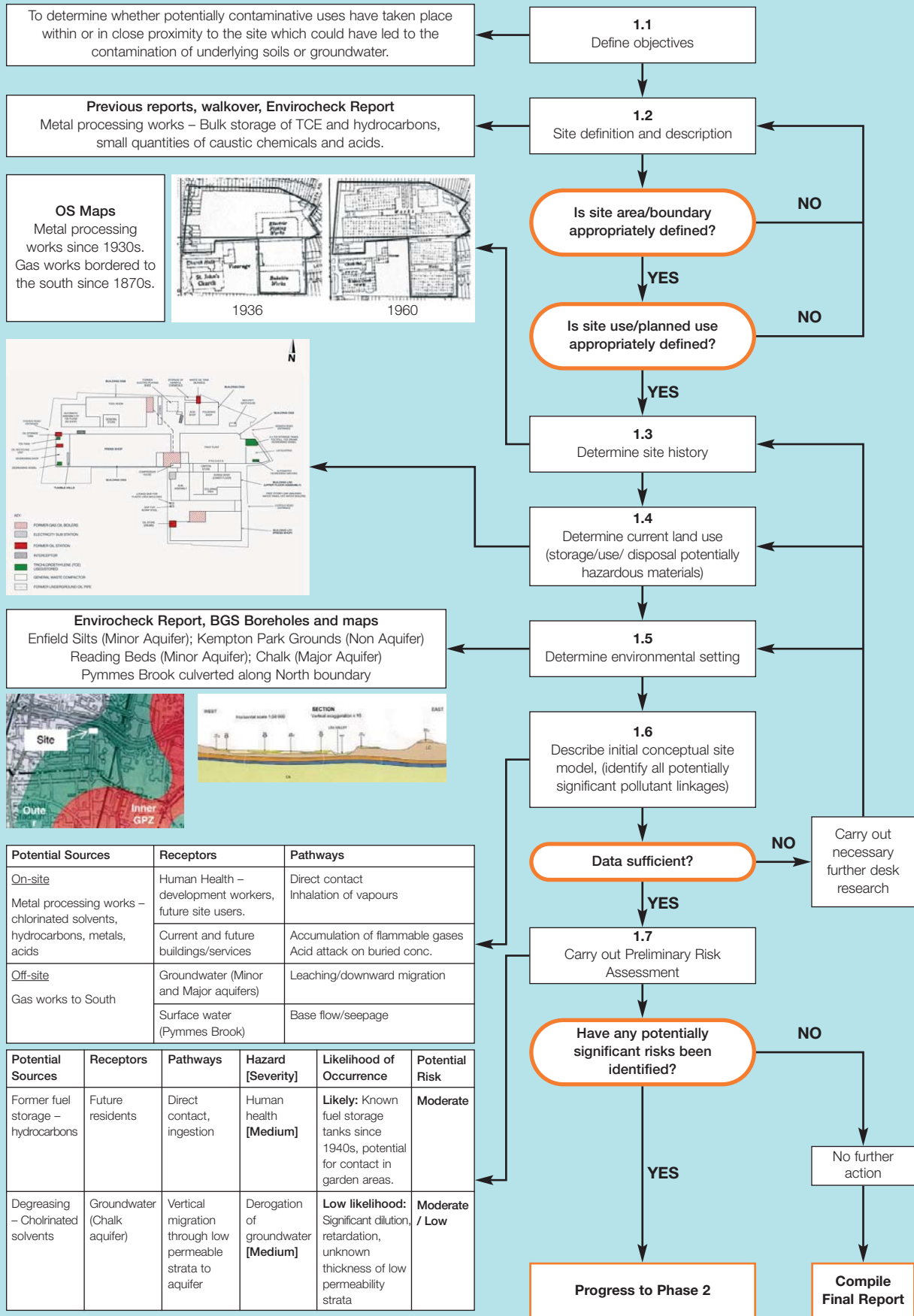
Case study

Overleaf a case study is presented in the form of the flow charts presented in Volume 1. The objective of this is to demonstrate how the process illustrated on the flow charts works on a real site. Key information from each Phase is included for each box. Only key parts of the case study project have been included to illustrate the process.

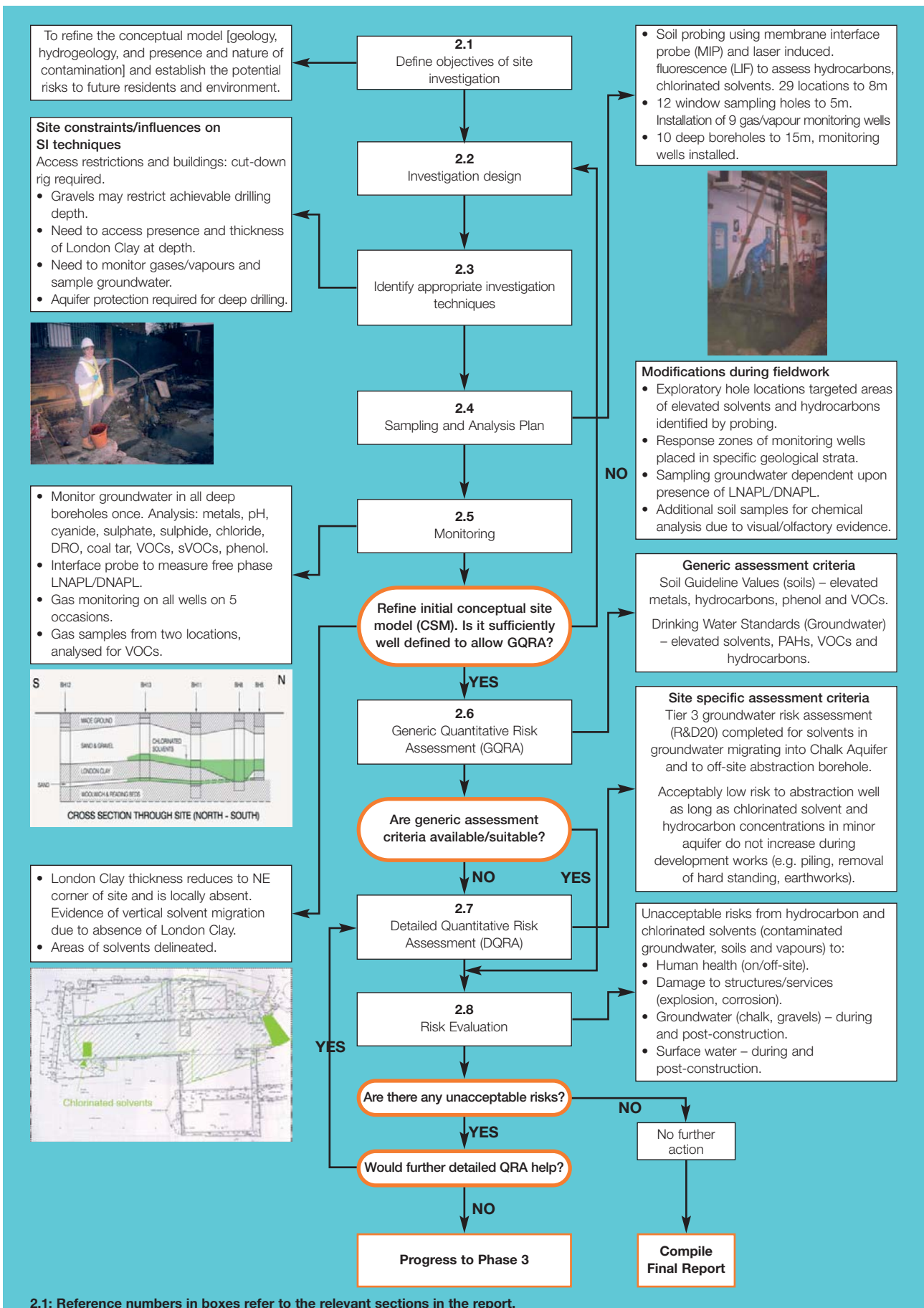
The site was historically a metal processing works with a history of hydrocarbon, solvent and chemical storage and use. It is located within a mixed residential and industrial area. The site is located within a groundwater protection zone (GPZ) associated with a groundwater abstraction for potable use. A groundwater abstraction well is located 450m from the site and uses water from a Major Aquifer at depth which is overlain by a Minor Aquifer at the surface.

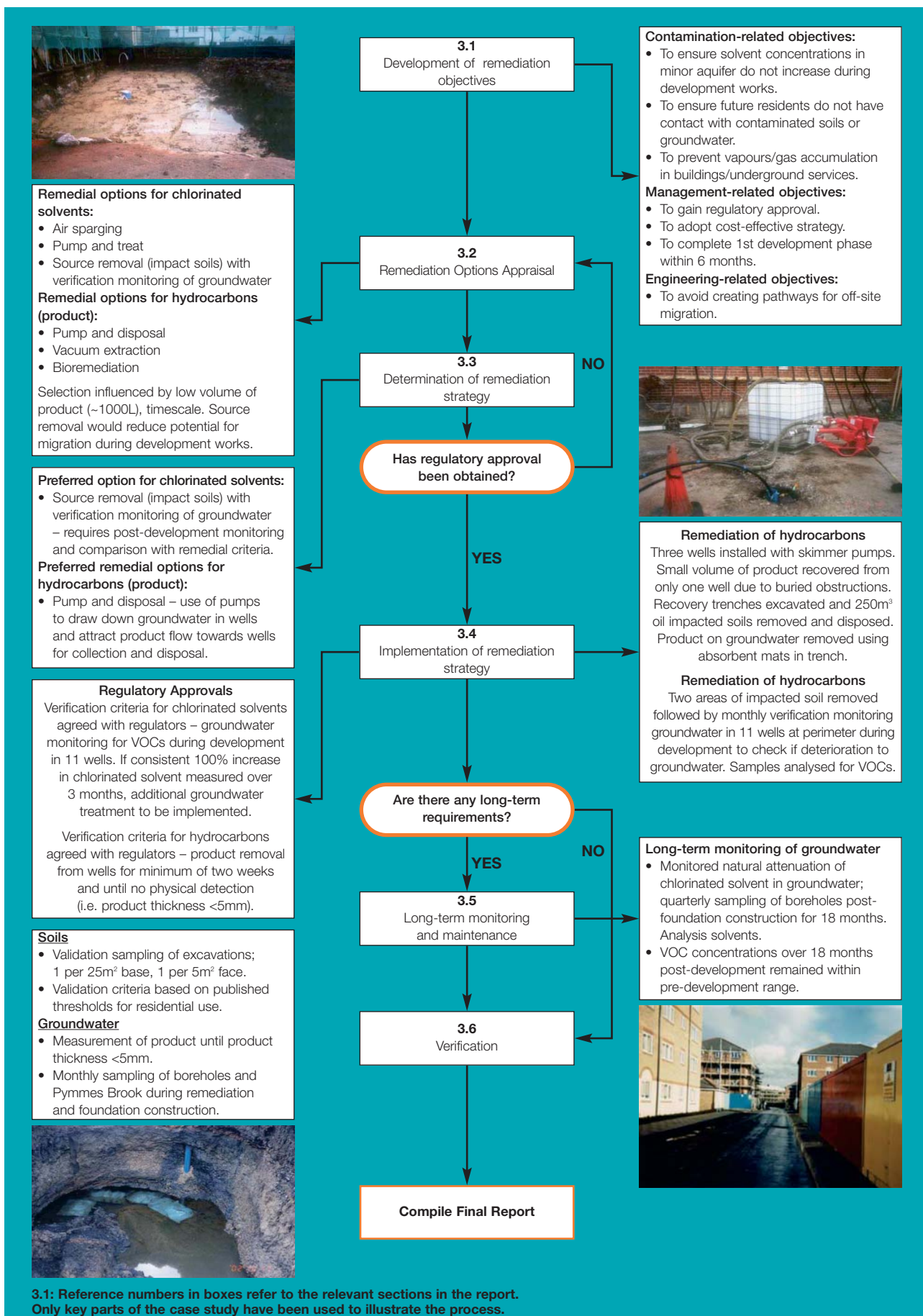
The Client was a developer who purchased a vacant site with the intention to redevelop it for residential housing. The consultant undertook a Phase 1 desk study followed by a series of progressively more targeted Phase 2 site investigations. Remediation design, implementation and verification were then undertaken.

The work was carried out to the satisfaction of the local authority and Environment Agency regulators and the site is currently occupied by residential flats and houses with private gardens. For the purpose of the flowcharts the main risks associated with hydrocarbons and chlorinated solvents have been selected and taken through the Phase 2 and 3 flowcharts. The increased understanding and refining of the conceptual site model, particularly with respect to potential pathways to the GPZ, is shown throughout the Phase 1 and 2 flowcharts. Extracts from sources of information used within the Phase 1 desk study, such as historical maps and geological cross sections have been included where they enhance the conceptual site model. Photographs showing investigation and monitoring techniques and remediation in progress have also been included.



1.1: Reference numbers in boxes refer to the relevant sections in the report.





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