ENVIRONMENT AGENCY

British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

Co-operating to manage contaminated land

A summary of the proceedings of an interactive workshop convened under the auspices of the British Geological Survey and the Environment Agency

on 3rd-4th November 1998 at
The British Geological Survey, Kingsley Dunham Centre, Keyworth, Nottingham

Navigation

HOW TO NAVIGATE THIS DOCUMENT

- The main elements of the table of contents are bookmarked enabling direct links to be followed to the principal section headings irrespective of which part of the document the user is viewing

- In addition, the document contains links:

  - from the table of contents to each principal section heading

  - from each page number back to the contents page

Return to contents page

Introduction

The interactive workshop on 'Co-operating to Manage Contaminated Land' in November 1998 was jointly sponsored by the British Geological Survey and the Environment Agency's National Groundwater and Contaminated Land Centre. It had a strong theme of co-operation and collaboration with organisations and individuals, from a wide range of backgrounds, and from other centres of multidisciplinary excellence in contaminated land. The meeting highlighted the need for us all to recognise the strength of working together, in partnership, realising the opportunities. This particular theme accords well with the development of the BGS's and Environment Agency's commitments, where the emphasis is on working in appropriate partnerships and delivering appropriate geoscience solutions.

The development opportunities and constraints presented by the natural environment arise from complex processes, relationships and interactions. Managing complex environments, such as those presented by land contamination, in safe and sustainable ways, requires integrated, multidisciplinary solutions. The core business of the British Geological Survey and the Environment Agency is to provide decision support and integrated solutions to Government, industry and the public. We must address problems and opportunities relating to the environment and, in particular, the issue of contaminated land and affiliated activities. These will naturally highlight applied R&D, which must focus on the needs and priorities of industry, in the context of compliance with environmental legislation.

It will be a rare occasion when any organisation can solve matters, like contaminated land, on its own and this is where partnerships, co-operation and collaboration are the key. While the BGS can provide direct solutions to many specific geoscience problems, it also has a role in assembling the geoscience data, information, knowledge, advice and expertise which supports customers in making their own decisions and finding their own solutions. This involves understanding a customer's business, seeing how geoscience impacts on the decisions they have to make, characterising and combining all the relevant geoscience information and then packaging the result in the right format for input into the decision-making process. As a regulatory body, the Environment Agency recognises the importance of relevant environmental data and information, and in particular the need to pull together areas of expertise for conducting investigations into land and groundwater contamination issues.

The activities during the workshop reflected both the British Geological Survey's and the Environment Agency's interest in the presentation and discussion of key opinions current in the field of contaminated land. This includes identifying the source of specific information and services. A review of the current methodologies and techniques, the integration of data sets and the practical application of R&D for remediation and management were central to the presentations and workshops.

During the evening reception, Mr Allen Rogers, Member of Parliament for Rhondda and a former geologist, gave a stimulating after dinner speech. He covered several aspects of the topic, but concentrated on mining and mineral extraction, viewing problems from a politician's perspective and suggesting possible ways forward. We thank Mr Rogers for giving his time to contribute to the occasion and for his thought provoking remarks.

David Falvey
Director, British Geological Survey

Bob Harris
Head of the Environment Agency National Groundwater and Contaminated Land Centre

Cover photo Sugden End landfill. Colin Waters, BGS © NERC

Contents

BGS services for contaminated land

Consultation on statutory guidance on contaminated land (Environmental Protection Act 1990, Part IIA: Contaminated Land) requires the local authority to inspect their area in order to identify contaminated land. There is then a responsibility to prioritise sites and identify those requiring remediation.

Contaminated land is identified on the basis of risk assessment in terms of the potential to cause significant harm. The local authority will be required to prepare, adopt and publish a strategy for contaminated land.

A pilot study undertaken by the BGS has established a method for the collation, display and interpretation of data in a GIS environment to fulfil the requirements of the draft guidance.

The BGS adopts a fully integrated approach to the collation of data within a local authority area relating surface and subsurface contaminants to present and former land use.

Land use

- collation and interpretation
- historical archive searches
- classification of land use
- identification of potential contaminants

Geology

- expert data acquisition and interpretation
- digital geological maps
- characterisation of contaminant pathways

Hydrogeology

- field testing
- data interpretation
- groundwater flow modelling
- contaminant transport modelling
- databases of aquifer properties

Engineering geology

- identification of made ground
- geohazard assessment
- engineering properties of rocks
- laboratory and field testing
- environmental geophysics
- risk assessment

Information technology

- collation and integration of geoscientific data
- GIS development and application
- training
- decision support systems
- map production

Geochemistry

- identifying contaminants
- characterising behaviour
- sampling soil and water
- sample preparation and analysis
- baseline geochemical data
- radon and methane detection

Regulation: the Environment Agency's role

Bill Baker, Environment Agency, 10 Warwick Road, Olton, Solihull, B92 7HX

Throughout the UK there are thousands of sites which have been contaminated by previous industrial use, often associated with traditional processes that are now obsolete, and which present a hazard to the general environment. The Environment Agency estimates that over 300 000 hectares of land are affected by contamination on between 5000 and 20 000 'problem' sites. Problems of contaminated land have been tackled almost exclusively in the context of redevelopment, where there was economic benefit linked to environmental enhancement. There is a growing requirement for land reclamation and development especially in view of the fact that recent government targets demand that 60% of new housing should be on 'brownfield' sites.

For 20 years redevelopment has been regulated by local authorities under the guidance of non-mandatory ICRCL publications. This unsatisfactory situation was addressed by the legislation in the Environmental Protection Act (1990) and the Environment Act (1995). With the enactment of this legislation and the formation of the Environment Agency, a much needed framework of regulation was provided.

Legislation controls threats to health and environment from land contamination. It is based on the 'suitable for use' approach to remediation and the 'polluter pays' principle is applied to the liability for remediation and related costs. Central to the system are rigorous risk assessment procedures supported by the Contaminated Land Exposure Assessment (CLEA) model approach.

The local authorities have a number of responsibilities with respect to contaminated land under the Act. These are outlined elsewhere in this volume, but briefly they include:

- inspections to identify contaminated land
- identification of the appropriate person or persons to bear responsibility for remediation of land
- decisions on what remediation is required and ensuring that it takes place and
- maintenance of a public register of their regulatory actions.

Responsibilities also devolve to the Environment Agency, the principal roles of which are:

- to provide site-specific guidance to local authorities
- to act as the regulator for any contaminated land categorised as 'special site'
- to publish a report on contaminated land and
- to make arrangements for carrying out technical research and to act as a centre of expertise.

The Environment Agency also has general responsibilities relevant to its work on contaminated land. These include advice on planning applications, dissemination of best practice, advice to the Department of the Environment, research and development and information exchange. The Environment Agency also undertakes other activities in areas of pollution prevention and control, including aspects of land contamination such as regulation of industrial processes, implementation of the Integrated Pollution Prevention and Control Directive, regulation of radioactive substances, prevention and minimisation of pollution of the water environment and the development of national regulatory policy for waste.

"... legislation controls threats to health and environment from land contamination. It is based on the 'suitable for use' approach to remediation and the 'polluter pays' principle is applied to the liability for remediation and related costs ..."

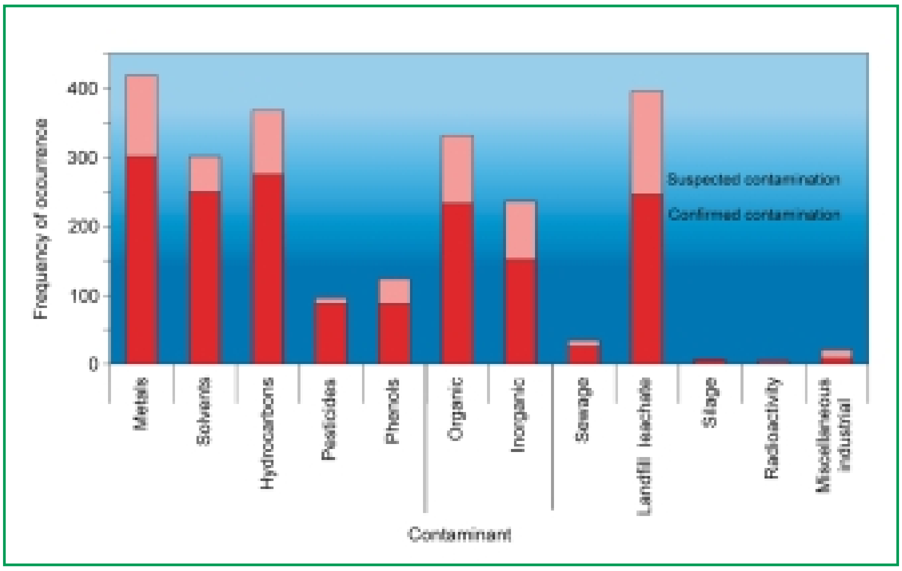
The Contaminated Land (Special Sites) Regulations were drafted to facilitate the determination of 'Special Site' Status. The regulations identify the type of contamination and the conditions by which a special site will be defined, including land associated with:

- pollution of controlled water
- contamination by certain chemicals used as pesticides
- contamination by waste acid tars
- refining of petroleum
- manufacture of explosives
- nuclear sites
- Ministry of Defence land and
- land on which IPC processes have been carried out.

Guidance has also been drafted. That relating to remediation includes a framework for development, notification and consultation, assessments, standards, monitoring etc. Guidance on the exclusion from and apportionment of liabilities for remediation, includes problems associated with costs and recovery, and presents recommendations to regulators and legal teams. The complex system of recovery of related costs, follows the 'polluter pays' principal, that is the person 'who caused or knowingly permitted the contaminating substance to be on, in or under the land'. However, if such a person cannot be identified, the liability transfers to the owner, occupier or state.

Although both the Environment Agency and the local authorities have their own areas of responsibility, for the objectives of the legislation to be successful, close collaboration between the two groups is essential, particularly in the context of assessment, remediation, redevelopment, regulation and guidance. The urgent need for training has been recognised and the Agency has sponsored the development of Procedural and Technical Guidance for the use of regulatory staff and is committed to a training programme in collaboration with the Local Government Association. In addition, central funding has been made available to support local authorities and the Environment Agency as joint regulators of contaminated land.

In conclusion, the Environment Agency looks forward to playing an important role, in partnership with others, in encouraging and promoting the regeneration of contaminated land and bringing it back into beneficial use as a contribution towards the realisation of the Agency's vision of 'a better environment in England and Wales for present and future generations'.



The frequency that particular contaminants occur in groundwater in England and Wales. The data are from a survey by the Environment Agency of groundwater pollution. *Graph reproduced from 'Groundwater — our hidden asset', a BGS Earthwise ™ publication.*

Regulation: the local authorities' role

Alan Higgins, Environmental Health and Trading Standards Service, Portsmouth City Council, Guildhall Square, Portsmouth, PO1 2AZ

Various estimates have been made of the number and area of contaminated sites in the UK, ranging from 200 000 sites to 100 000 hectares, with an estimated cost of remediation being counted in billions of pounds. The legacy of the industrial development of the UK has been an issue that has taxed politicians and regulatory bodies significantly over the last 10 to 15 years. During the last five years the House of Commons Environment Committee has published a number of reports and consultation documents and their Framework for Contaminated Land (1994) subsequently resulted in the enactment of the Environment Act 1995.

The policy document and and the Act endorses the Government's commitment to the 'suitable for use' approach to the control and treatment of existing contamination and requires remedial action only where:

- the contamination poses unacceptable, actual or potential risk to health or the environment and
- there are appropriate and cost effective means of being able to do so, taking into account the actual or intended use of the site.

It also supports the principle of 'the polluter pays'. Many other European countries take a different approach, so that after remediation a site should be suitable for any use, not just the use for which it is intended. Our continental partners are finding this very expensive option difficult to sustain.

Few studies emphasise the trauma that occurs when a site previously believed to be suitable for its current use is suddenly found to be contaminated and presenting a risk to its occupants. If it is a site for public use (housing, schools) then the trauma for residents, politicians and environmental health officers is immense. The Environment Act sees local authorities as the key bodies in dealing with contaminated land issues.

"... few studies emphasise the trauma that occurs when a site previously believed to be suitable for its current use is suddenly found to be contaminated and presenting a risk to its occupants. If it is a site for public use (housing, schools) then the trauma for residents, politicians and environmental health officers is immense. The Environment Act sees local authorities as the key bodies in dealing with contaminated land issues ..."

Local authorities in England and Wales have a number of roles in relation to contaminated land. There are various planning controls in which contaminated land is a material planning consideration, including the redevelopment of brownfield sites. The Department of the Environment, Transport and the Regions considers that 90% of contamination issues should be dealt with through the planning process. There are also reponsibilities relating to waste management and disposal. The Environment Act gives consideration to proportioning responsibility and liability for the remediation of contaminated sites and this is relevant to local authorities that have substantial land holdings, some of which will be contaminated waste disposal sites. Local authorities also have the responsibility to promote economic development in their areas through planning, building partnerships, services to business and facilitating various grant applications including regeneration.

Legislation, such as The Environment Protection Act (1990) and the Environment Act (1995), has direct implications to the local authority's role regarding past contamination of land (e.g. asbestos on sites, landfill gas migration, hazardous waste). Planning controls and building controls are also relevant. Future contamination is also covered by these Acts in terms of authorisation and management of disposal of controlled waste. So provisions require local authorities to:

- identify and take action in respect of contaminated land in their area
- carry out inspections
- decide if land should be designated a 'special site'
- establish who the appropriate persons are to bear responsibilty for remediation of land
- serve remediation notices and
- maintain a register of remediation notices, appeals, remediation statements and declarations as well as convictions.

Local authorities need to establish a strategy for action which should include:

- identification and prioritisation of sites (site investigations and risk assessments should recognise specific environmental risks, the source of the substances and the harm caused to humans, ecological systems, buildings, animals, crops and water),
- information requirements (registers)
- redevelopment needs (this is the main opportunity for remediation so the local authority should have a strategy to acquire information on which to base their advice on redevelopment)
- the process for dealing with sites that fall outside the Environment Act (1995).

In order to carry this out, there are various practical issues concerning consistency of approach, training requirements, relationship with the Environment Agency, resources and guidance.

In conclusion, recent legislation provides some significant opportunities to deal with contaminated land, but fails to deal with some of the significant issues related to the redevelopment process of previously contaminated sites. This is unfortunate beacause only a few sites will fall within the remit of the Environment Act (1995). Most sites will have to be remediated as and when they are redeveloped.

There is a significant burden on local authorities for which they must be prepared. In some cases there will be long, technically complex and expensive litigation which may discourage some Local Authorities from being proactive in their approach to contamination. It is also likely that there will only be limited resources for the remediation of contaminated land or to support local authorities carrying out their responsibilities.

Alan Forster, BGS © NERC

The East Merthyr Reclamation Scheme in South Wales. The scheme involved the removal and safe disposal of iron smelting slag from a derelict industrial site above old shallow mine workings followed by an open-cast operation to recover coal from the pillars of the abandoned shallow workings and to extract additional coal from below the old workings. Finally, the site was infilled, landscaped and restored to a condition suitable for housing, other industrial or recreational use.

Contaminated land management

Paul Nathanail, Land Quality Management, School of Chemical, Environmental and Mining Engineering, University of Nottingham, University Park, Nottingham NG7 2RD

Something in the order of 200 000 tonnes of waste, including 248 identified chemicals, were dumped on the Love Canal site in Niagara City over several years. It was then sold to the Board of Education and housing and a school were built. Between 1977 and 1987 it was recognised that chemical contaminants had effected the dwellings. Eighty-two chemicals were identified in the groundwater, including eleven carcinogens. The site was declared a federal disaster area and 239 families had to be evacuated. Medical problems attributed to the contamination were identified amongst the inhabitants only when media interest was high. Testing was carried out on epidemiology of low birth weight of infants and the stunting of growth. However, some of the results were disputed.

The value of risk assessment has applications not only in identifying implications of contamination on health, environment and buildings, but also in the field of cost evaluation and insurance. A conceptual model can be built up initially in order to understand the site. In any situation the sources of contamination, the pathways by which contaminants move and the targets effected (buildings, animals, humans) have to be identified. Aspects such as the geology, hydrogeology, climate and physical and chemical processes have to be understood. Only after this has been done can work begin to remove or neutralise the source, divert or block the pathways and protect the targets. Only then can remedial action can take place.

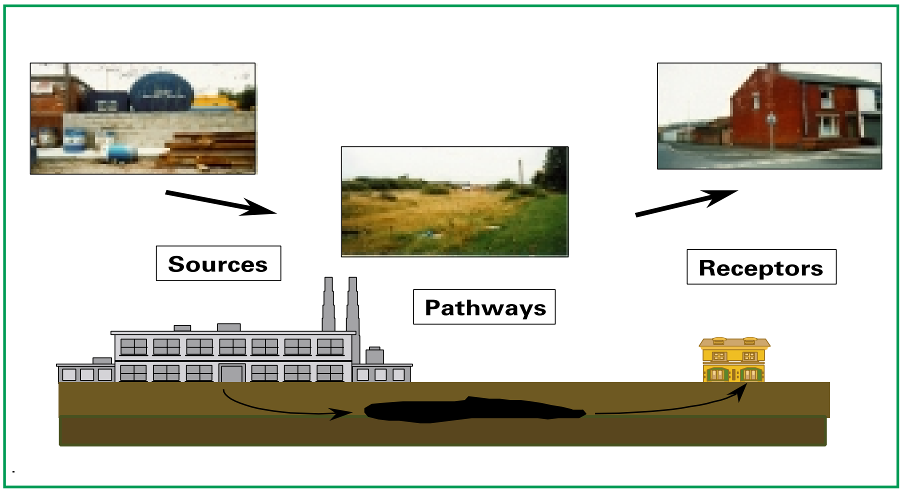
Risk assessment helps to:

- identify the hazard
- assess the relationship between exposure (or dose) and adverse response by means of laboratory tests, epidemiology and computer modelling
- assess risk associated with exposure by considering the intensity, frequency and duration of exposure to the hazard and
- identify the nature of the risk using all the information at hand to form an expert judgement.

Assessment may include the history of the site, chemical sampling of soil and groundwater, the degree of exposure and epidemiology studies (on human and other organisms). Some risk may be acceptable so long as it is controllable, understood, affects only a small area or is not catastrophic. Contaminated land may be fit for some purposes and with remedial action may become fit for others.

> ***"... the value of risk assessment has applications not only in identifying implications of contamination on health, environment and buildings, but also in the field of cost evaluation and insurance ..."***

Communication is important in risk assessment. The levels of carcinogens and toxins, together with the risks associated with them and the possible financial considerations should be spelt out. These may be human health risks, ecological risks, risks to water resources (by the dispersion of pollution in groundwater and surface water) and risks to construction materials. In this respect computer modelling is becoming a vital tool in risk assessment and there are many packages that model dose-response, exposure and risk characterisation. Modeling of human intake for different land use helps to answer questions such as what is the exposure and, by comparison with 'tolerable daily intake', is the exposure acceptable? Using CLEA or other appropriate models it is possible to compare soil concentration with guideline values and indicate where remediation or site-specific risk assessment is necessary. Guideline values indicate whether a site is safe or not. They do not predict how many people will die, nor compare measured risk with estimated risk. Exposure assessment is an important tool in such aspects as base line studies for local authorities, spatial risk assessment and identification of how problems of contamination can be remediated, bearing in mind financial risk. It is cost effective to consider risk at the outset of a project and let risk considerations drive information collection and interpretation.



The conceptual model drives contaminated land management (figure courtesy of Shell UK).

Regulation and enforcement

Malcolm Lowe, Department of the Environment Transport and the Regions, Room 3/B5, Ashdown House, 123 Victoria Street, London SW1E 6DE

The aims of the workshop on regulation and enforcement were to address four questions:

1 What is contaminated land?

2 Why regulate it?

3 When do we regulate it?

4 How do we enforce regulation?

These questions raised some important issues for debate. The concepts of risk, the importance of understanding source–pathway–target relationships and the sustainability, remediation and prevention of contamination problems were discussed. This was followed by consideration of the appropriateness of waste management legislation (WML) regimes to control aspects of remediation. The existing legislation proved an area of great interest and was discussed at some length including aspects such as statuary nuisance provision. Consideration of new legislation revolved principally around Part IIA of the Environmental Protection Act and the relative effectiveness of primary legislation, statutory guidance, regulations and technical advice.

The key outcomes of the debate were:

- agreement that regulation of contaminated land and remediation is desirable, but that WML is not necessarily the best mechanism to achieve it
- there is a need for proper funding and guidance before the new legislation is enacted.

In conclusion, better controlling mechanisms are required rather than WML. Guidance is needed on regulation and enforcement and there must be better awareness of regulating and enforcement criteria.

Protocols for acquisition and data management

Barry Smith, British Geological Survey, Keyworth, Nottingham, NG12 5GG

Land is an important resource with a number of essential functions including:

- providing a reserve of potable water
- acting as a protective filter for groundwater resources
- being the source of raw materials
- acting as a support medium for plant growth
- providing settings for recreation and tourism
- providing a structural base on which to build and
- maintaining habitats and biodiversity.

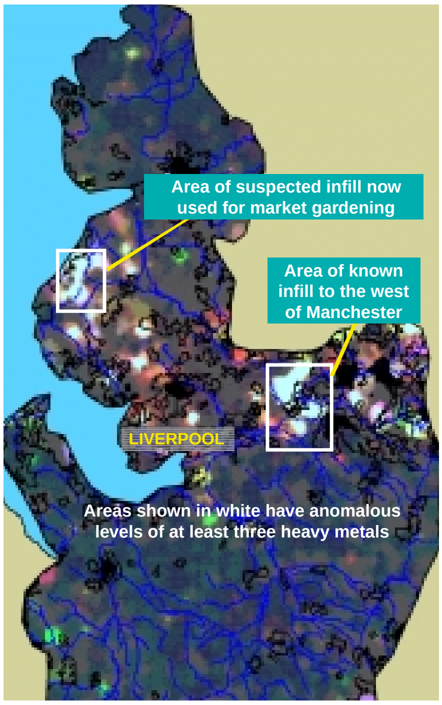
The quality and classification of the land, which reflects its capacity to maintain these functions, depends on the complex chemical, biological and physical properties and interactions of the soil, water, air and biota within it. Land quality and/or contamination may therefore be considered as a measure of all current positive or negative properties of the land which impact on its use. Alternatively, contaminated land can be defined as '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' (the Environment Act, 1995).

Methods used to determine the presence of substances likely to cause harm and techniques used to collect, collate, analyse and archive data must be applicable and scientifically sound. Responsibilities placed on councils and local authorities (by Part IIA of the Environment Act) and on national governments (by the European Union) put emphasis on the the integration of data at a variety of scales, ranging from traditional local site investigations to regional, national and trans-boundary studies.

Although studies at the larger scale inherently require a more systematic approach, there are considerable benefits to be gained from encouraging the amalgamation of best practice across a wide range of scales. For example, particular difficulties exist in recording and comparing contextual data collected by different contractors, in comparison with the collection and collation of chemical or physical data during the analysis of a particular hazard.

> *"... the quality and 'contaminated' classification of the land, which reflects its capacity to maintain these functions, depends on the complex chemical, biological and physical properties and interactions of the soil, water, air and biota within it. Land quality and/or contamination may therefore be considered as a measure of all current positive or negative properties of the land which impact on its use ..."*

Providing a robust, transparent methodology for acquiring data is vital. An important step forward is the continued development of documentation, recording and publicising best practice through for example international, national and client specific standards in the context of site specific investigations and national surveys. However, the development of methodologies and standards relating to the management and visualisation of such data once collected is less well developed. This is in part due to the rapid

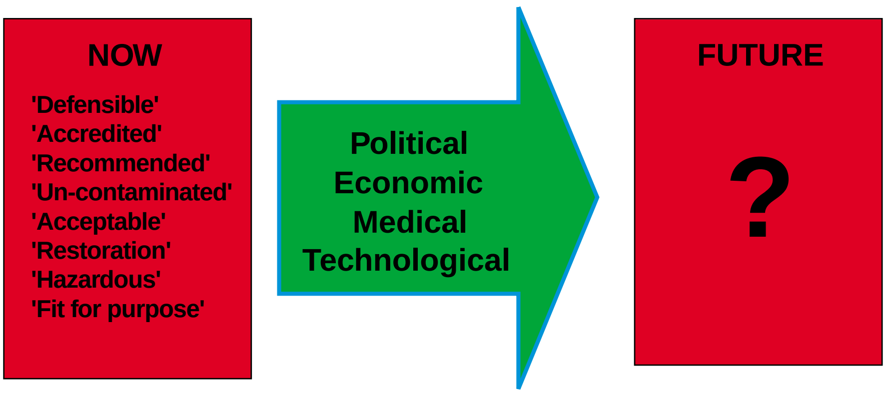


Neil Breward and Barry Smith, BGS © NERC

Systematic surveys at a range of scales may be used in conjunction with suitable historic data to define and relate sources of potential hazards and displayed by the use of GIS. An example at the regional scale is shown in this composite map of copper, lead and tin for soils in Lancashire and Cheshire.

rate at which new technologies such as geographical information systems (GIS) are being developed and introduced, and in part due to the high cost and the diverse nature of data management and copyright issues. Despite such difficulties, the use of tools such as GIS to improve our understanding of contaminated land, at a range of scales, is a prerequisite in unravelling and recording the interaction of multiple sources of hazardous contamination to a wide range of spatially distinct receptors.

In addition to the integration and interpretation of existing data, the assessment of contaminated land and land quality requires the collection of new data. New standards and standardised methods continue to be developed at international, national and local scale. These guide investigators into a systematic approach to the investigation of contaminated land, that avoids the majority of the pitfalls identified over the years. These include issues such as sampling, chemical analysis, quality assurance, quality control, accreditation, inter-comparison, identification of appropriate determinants and data interpretation. However the development and drafting of such methods, particularly at the international level, takes time and there is a significant lag between, for example, developments in analytical methodologies or the range of parameters required for risk assessment (such as bioavailability) and the development of approved standard procedures. This places particular emphasis on the continued development and communication of best practice and technical development, at a professional level, amongst regulators and consultants involved in contaminated land issues, as well as the active involvement of practitioners in the development of appropriate, transparent, standardised protocols.



Protocols for acquisition and data management — common assumptions are extremely sensitive to change which precludes over-prescription of protocols and guidelines.

Site investigation and risk assessment: a pragmatic approach for the UK

John Lapinskas, DG Environmental Ltd, Pinnacle House, 23–26 St Dunstan's Hill, London EC3R 8HL

Risk prioritisation with regard to contaminated sites is a major concern for industry, the public sector and former military installations. The legacy of past polluting practices has resulted in contaminated sites, which today present complex and challenging problems. Any solutions will require a multidisciplinary approach combining civil engineering, chemistry, geology, hydrology, toxicology, GIS, CAD/Microstation and environmental science. Contamination by hydrocarbon products is the most widespread.

Soil and groundwater contamination have recently become major concerns in the UK, but approaches to resource management with respect to environmental auditing, risk assessment, site investigation, and remediation strategies have presented difficult technical, scientific and regulatory challenges. Hydrocarbon contamination from leaks and spillages, which is now a key issue in the protection of groundwater resources, is greatly dependant on underlying hydrogeological conditions and physical characteristics of the soil, as well as the physical and chemical properties of the organic materials themselves.

Among the contaminants found on major industrial sites (heavy metals, asbestos, inorganic chemicals etc), most problematical are petroleum hydrocarbons. They have become very widespread because they are used in derv, lubricating oil for machinery, gas oil and heating oil, chlorinated solvents, aviation fuel and so on. The various types of petroleum products differ chemically and so behave differently as they move through soil and water.

There are several key aspects of environmental risk:

- the nature, concentration, characteristics and extent of surface and soil contamination on a site
- the ease by which contaminants can migrate
- the potential impact on surface water courses and underlying groundwater aquifers
- the volatile nature of different hydrocarbons
- airborne contamination of inorganic dust particles of asbestos and heavy metals like lead and metalloids such as arsenic
- the risk to human and environmental targets
- development of quality objectives and cleaning methods.

Contamination assessment usually begins with a desk top study. In an environmental context, investigations include geological, hydrogeological and hydrological information as well as site history and layout (documents, environmental audits, maps, photographs, local archives and knowledge, housekeeping and waste management practices, etc.). All potential environmental hazards and migration pathways should be identified and assessed.

After the desk top study it may be necessary to carry out a comprehensive site investigation. Historical data may indicate the areas most likely to be contaminated and hot spots of highest contamination. Sampling should be carried out in a methodical way so as to be statistically valid, to ensure there is no cross contamination of samples by soil or water and to see that samples are stored appropriately.

The information gathered allows a remediation strategy to be developed in consultation with relevant authorities such as the Environment Agency, local planning authority and waste regulation authority. Factors influencing the strategy must be identified, including the nature and extent of the contamination, environmental liability, type of development, residual hazards and engineering and planning restraints. Remediation options can also be identified, such as on-site or off-site disposal, encapsulation by barrier systems and on-site treatment, but an option may also be that no action is necessary. Remediation technology for contaminated soil or water may be physio-chemical e.g. landfill, thermal treatment, chemical treatment, soil washing; or biological, either on-site or off-site.

In conclusion, by adopting a professional, multi-phased approach to assessment and investigation of contaminated land, hydrocarbon contamination can be identified and measured. A cost effective and successful remediation strategy for the soil and groundwater contamination, on active and derelict industrial sites, can then be put into place.

Non-biological remediation methods

Steve Wallace, Lattice Property Holdings, Wharf Lane, Solihull B91 2JP

The primary aims of the workshop were to explore the differences between alternative non-biological remediation technologies and the 'dig and dump' methods and to investigate what barriers exist in using such technologies. Amongst the main issues concerning the different technologies, it was recognised that the boundary between biological and non-biological methods is artificial; there are situations where both can be used. It can be shown that barriers to implementation exist, one of the more obvious examples being waste management licences.

The Basford Gasworks, Nottingham, can be used as a case study of non-biological remediation methods. Basford is a typical gasworks. It opened before 1854, but was expanded and modernised in the 1930s and again in 1959. It ceased production and was subsequently demolished in 1972, but the site has been used as a depot and gas storage/distribution centre to the present day. A reclamation strategy was agreed between Nottingham City Council and the Environment Agency and pilot study was carried out to see if soil washing was the solution to the contamination.

A number of concerns about non-biological remediation technologies were revealed. There was the problem of confidence in the treatment technologies. Financial implications were also a concern; costs could be offset against landfill costs and there was the on-site versus off-site question. Soil washing also required specialist contractors and subcontractors, which may cause management problems.

There are several advantages to soil washing. It reduces disposal to landfill, reduces the need to import clean fill and it reduces the amount of traffic movement to and from a site. However, its economic viability depends on such aspects as the scale of the contamination problem and the chemical and physical characteristics. Soil washing works for gasworks contamination and is cost competative with 'dig and dump' methods and the knock-on benefits may be significant. On the other hand, the risk/reward balance needs to be considered.

A number of barriers to soil washing were discussed during the workshop. There may be confidence barriers for lay people in terms of the adequacy of the cleaning and those funding the operation in terms of the development time-scale. It is important that the end use of the land is known before choosing which technology option is appropriate. The scale of the site is also a factor; small sites may not be viable due to the large cost of mobilisation. Perhaps there is a need for a 'mother site' where materials from a number of smaller sites could be taken for cleaning, although there may be difficulties under current waste management licensing regulations.

Several key outcomes were identified during the workshop.

1. There is a need to consider physical contamination as well as chemical contamination especially when dealing with difficult ground conditions.
2. Careful consideration has to be given to logistics, costs and time-scales involved in remediation.
3. There is a tendency to be conservative with cost estimates, principally due to the lack of data and examples.
4. There must be support from the regulators on the use of new technologies, although there must be good verification testing to prove that they are effective.
5. Finally, the advantages of waste minimisation to the environment were recognised.

Liabilities

Simon Johnson, CERTA (UK) Ltd, America House, 2 America Square, London EC3N 2LU

The aims of the workshop were to explore the range of liabilities associated with ownership, transfer and management of contaminated land and environmentally suspect land and to identify the range of methods employed to control, manage, avoid and limit liability. The main topics discussed were:

- the perception of unacceptable risk and/or uncertainty
- land contamination risks and owner/buyer liabilities, warranties etc.
- categories of risk; how do liabilities arise and how are they ranked in importance
- consequences including financial, health and safety, environmental impact, and public relations
- managing liabilities, including avoidance limitation and control
- transfer of liabilities to a third party by insurance, collateral warranties etc.

Against the backdrop of tightening legislation, certification and insurance solutions have been designed to help businesses manage land contamination. The object is to turn business uncertainty into certainty, thereby enhancing the value of the land while protecting against potential liabilities. Computerised audit systems capture and incorporate recognised good practice in assessing, controlling and remediating contaminated land and auditing protocols covering all aspects have been produced. Protocols cover tiered risk assessment and remedial action including risk management.

The contaminated land and land certification protocol covers:

- Phase 1 risk assessment aims to establish whether there are any historical or current contaminating activities carried out on or in the vicinity of the site, taking into account the actual or intended use of the site as well as its environmental setting. It should address contamination sources, pathways of contamination and the receptors of the contaminants and the linkages should be represented in a conceptual model. All sources of information consulted are referenced and reported. It is the consultant's responsibility to ensure that adequate information has been collected and assessed and where pollution is identified there should be sufficient information to establish what investigations and work is required in a Phase 2 risk assessment.
- Phase 2 risk assessment aims to characterise the site in detail in order that risks to human health and environmental risks can be estimated and evaluated, as well as to build on the information on pollutant linkages identified during Phase 1. It usually includes site investigation work, including on-site testing, analysis of soil and water, leachate, gas and so on. Reports from Phase 2 risk assessment should allow decisions to be made as to the acceptability or otherwise of the risk estimates and establish any further measures that are required to control or reduce risk.
- Phase 3 is one of remedial action. This usually includes a series of risk management activities to reduce and control risks to humans and the environment. After evaluation of remedial strategies remediation actions and programmes are designed. Once these are implemented, monitoring can take place to ensure the actions are effective. On completion of the remediating activities site status can be confirmed and long term monitoring and maintenance activities can be put in place.

Colin Waters, BGS © NERC

Methane venting at a site west of Bradford.

The presence or suspicion of contamination has an adverse impact on land values. This is partly due to cost of remediation and partly due the stigma, reflecting the perceptions, suspicions and confidence of purchasers and lenders alike. For this reason, it is important to assess contamination and its threat to human health and the environment (especially ground and surface waters). These assessments should go beyond the technical detail and include a wide range of related engineering, financial, economic, legal and socio-political issues. Risks and liabilities need to be evaluated and the results communicated unambiguously to all involved, together with a management strategy leading to effective, safe and economic solutions. The purpose of this is to protect, maintain and improve land and property assets.

Good management is essential and should include:

- technical risk management including assessments, strategy development, quality assurance and control, high work specification and performance guarantees
- financial risk management e.g. make long term provision on company accounts; transfer liability by indemnities, warrantees and so on; various financial tools such as escrow accounts and bonds; and insurance
- legal and regulatory risk management including various environmental compliance, environmental health safety planning, management and supervision and compliance with planning conditions.

One of the tools available to manage contaminated land is the transfer of liabilities to others and there are several ways in which this transfer can be accomplished:

- consultants' professional indemnity insurance protects the consultancy against negligence claims
- collateral warranties, which are signed by professional advisers and consultants
- public liability insurance policies, which are restricted to sudden accidental events and resultant pollution and
- specialist insurance designed to support business in reacting to specific types of event such as gradual pollution or the discovery of historical contamination.

Where it is known that a site is contaminated, insurance is not appropriate, but there is always a residual risk once a risk assessment has been completed or remediation started. This may have an adverse impact on property values and impede redevelopment, but it is insurable.

In conclusion, effective management is strategic management not crisis management. It is not possible to avoid liability totally, but it is possible to manage, limit, control and/or transfer those liabilities. There is an increasing tool box to assist all parties involved with contaminated land, but uncertainty remains high in many legal and technical areas.

Information and GIS

Jenny Walsby, Andrew Marchant* & Sarah Dack**,*
**British Geological Survey, Nottingham, Keyworth, NG12 5GG*
***DG Environmental, Pinnacle House, 23-26 St Dunstan's Hill, London EC3R 8HL*

The aim of this workshop was to examine issues, ideas and problems of implementing GIS in local authorities in relation to site specific data and contaminated land legislation. Using GIS for site specific data has a number of advantages in terms of data integration, transfer, manipulation, usability and communication. Digital maps and their associated attributes are a lot more expressive than text and can be a great help in visualising and interpreting data. Applications of GIS in the BGS include the Address-Linked Geological Inventory (ALGI) which has site specific reports on ground conditions; Urban Geosciences for Newham, an integeration of multi-disciplinary data sets and identification of potential contaminated sites; the Geoscience Data Index, a graphic index for national enquiries; and site assessments such as that for a repository for radioactive waste.

Legislation relating to contaminated land (Part IIA, Environmental Protection Act 1990), requires all local authorities to produce a strategy for managing contaminated land. This strategy involves identifying sources, pathways and targets. Due to the vast quantities of data involved and the spatial nature of the data, GIS provides an ideal solution. A typical contaminated land GIS may contain information on known contaminated sites, landfills, landuse, geology, hydrogeology and geochemistry. These datasets form individual layers in the GIS which can be displayed individually or in combination.

As well as displaying data, the GIS can be tailored to perform a number of functions required by its users, such as:

- generation of standard reports containing relevant information about a site and its surrounding area
- prioritisation of potentially contaminated sites in terms of remediation (based on surrounding features such as landuse and water features).

GIS has been under-exploited within local authorities due to a lack of understanding of its capabilities and the problems to which it can be applied. There is now significant interest in its use for managing contaminated land, although a number of issues need to be addressed in terms of data availability, cost, data quality, software and the Internet.

Data can be relatively cheap to buy if it already exists in a digital form (for instance 1: 10 000 scale geology for London). However, knowing what digital datasets exist and where they can be found is a problem. This problem is currently being addressed in a joint British Geological Survey/Environment Agency project aimed at producing guidance for the use of digital environmental data.

Converting other datasets, such as landuse, into a digital form can also be problematic. Digitising paper maps by hand is a slow and expensive process, whilst scanning in maps may be cheaper and quicker but results in a dataset that is no more than a picture (i.e. no information is stored on individual features on the map). When using data from outside organisations it is important to take account of any confidentiality and copyright issues, for example whether the data can be converted to a digital form, and whether it can be passed on to third parties.

Users generally perceive GIS data to be perfect because it is stored digitally, however, there can be a number of hidden errors:

1 *Data entry* Features may have been incorrectly digitised or the original paper map may be inaccurate if it has been stretched or folded.

2 *Scale misuse* Data of vastly differing scales should not be mixed. For example when looking at an individual site, it would be inaccurate to use geology digitised at a scale of 1:250 000.

3 Combining layers only increases the potential for error as the information shown is only as good as the worst layer displayed.

The functionality and ease of use of the final GIS depends on the GIS software used. There is great variability in the available packages in terms of basic functionality (e.g. queries and searches available), customisation of the GIS, compatibility with other GIS packages (importing of data in other formats), and the quality of support from the manufacturers.

There is a growing interest in making GIS applications and datasets available over the Internet. Although this will be very powerful in terms of querying GIS applications from remote locations and exchanging datasets, there are some hidden dangers. It will become very easy for anybody to build their own GIS by downloading datasets from various remote locations with no knowledge of the scale, projection or accuracy of the dataset and thus make decisions based on unsuitable or inaccurate data. Guidlines are needed because although there is a need for openness and sharing information and data in the public domain, the standardisation of data sets is vital as is responsible use of data to avoid misinterpretation and potential blight.

Several conclusions were drawn:

1 Both the Environment Agency and British Geological Survey see the need for greater standardisation of GIS methods and data formats within Earth/environmental science and the UK in general.

2 The information used by environmental organisations should be more freely available so that it can be used more widely and enable the provision of better or joint services.

3 Legistlation is needed to enable open data management and use.

4 Issues such as blight require investigation and responsible use of GIS.

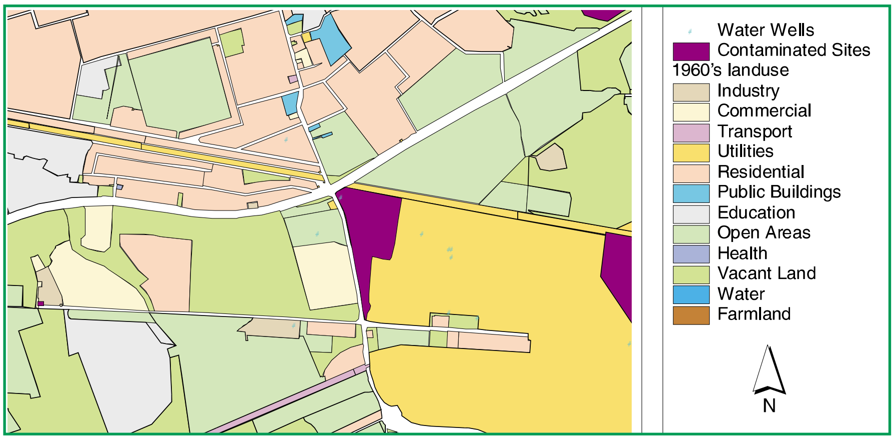
5 There are training issues associated with the use of GIS regarding the provision and manipulation of data that may lead to blight.

6 Best practice, information exchange, openness and cost benefit of cheap hardware and software needs to be investigated for GIS and some UK-wide protocols established.

7 The issues of GIS data quality, data scales and fit for purpose products need greater publicity. Standard procedures and practices should be established.

8 Data deficiencies need to be identified as part of any risk assessment. More communication within the GIS community is required and users need to be made aware of data limitations.

9 The advantages of GIS as a tool for interpretation and communication of data and information should be promoted in the contaminated land community. Pictorial information often communicates more powerfully than text and it is important that database information is readable and clear.



Andrew Marchant, BGS © NERC

A water well has been identified in an area of untreated contaminated land. Depending on the current state of the water well, it could potentially transport contaminants to the underlying aquifer.

Natural attenuation of contaminants

Phil Morgan, Eutech, Daresbury Park, Warrington WA4 4BT

Natural attenuation comprises the naturally occurring processes in soil and groundwater that act, without human intervention, to reduce the mass, toxicity, mobility, volume or concentration of contaminants. The processes involved include biodegradation, dispersion, dilution, adsorption, volatilisation and chemical or biological stabilisation or destruction of contaminants. There are several lines of evidence that natural attenuation is effective, including an observed reduction in contaminant concentrations at different points along the path of migration, documented loss of contaminant mass on the field scale (using geochemical analysis data and estimation of transport parameters) and laboratory microcosm data. The use of natural attenuation can be demonstrated with reference to hydrocarbons and chlorinated solvents.

It is possible to treat a number of compound groups by bioremediation. These include landfill leachates, petroleum hydrocarbons (including Polynuclear Aromatic Hydrocarbons — PAHs), chlorinated solvents and aromatics, phenolics, pesticides and certain inorganic groups. Hydrocarbons can be used as a carbon/energy source aerobically and, for some compounds, anaerobically. The capacity of the groundwater for biodegradation can be calculated, based on the stoichiometry of the biodegradation reactions. To illustrate the natural attenuation of hydrocarbons, two case studies can be considered.

The first example of hydrocarbon natural attenuation comes from a UK oil distribution terminal where there had been a gasoline additive release early in the 1970's. The natural attenuation has been monitored since April 1994 and several lines evidence for mass removal of contaminants by biodegradation have been recognised. Primary lines of evidence include the observations that the movement of contaminants has stopped, the area of contamination is reducing and benzene concentrations are decreasing. Secondary lines of evidence include geochemical evidence of O_2, NO_3^- and SO_4^{2-} depletion with increasing benzene/toluene/xylene (BTEX); and microbiological evidence such as the high microbial numbers and large sulphate-reducing population. A second example is natural attenuation of chlorinated solvent contamination in groundwater at Dover Air Force Base, USA. There are three lines of evidence for natural attenuation. The first comes from the observed reduction in contaminant concentrations along the path of flow. The contamination has not travelled from the source area as far as it would without natural attenuation and the distribution is not as expected — vinyl chloride (VC) has not gone farther than trichlorothene (TCE). Secondly, a loss of contamination mass on the field scale is recognised by extensive data monitoring and transect study (using standard interpretative methods and statistical analysis), geochemical evidence (which is in line with current conceptual models of biodegradation patterns) and chloride mass balance (approximately 120kg of chlorinated hydrocarbons (CHCs) are degraded each year). The third line of evidence comes from laboratory microcosm data, which demonstrates the capacity of biodegradation (reductive dechlorination in the centre of the contaminated area and direct oxidation of dichloroethene (DCE) and VC downstream) and the fact that the calculated half-lives compare with values given in the literature.

Jonathan Chambers, BGS © NERC

Tar pit, Derbyshire.

"... there are several lines of evidence that natural attenuation is effective, including an observed reduction in contaminant concentrations at different points along the path of migration, documented loss of contaminant mass on the field scale (using geochemical analysis data and estimation of transport parameters) and laboratory microcosm data ..."

Developments in the evaluation of natural attenuation, including hydrocarbons and chlorinated solvents, are given in a number of guidance documents. NOBIS (a Dutch research programme on in situ bioremediation) gives guidance on hydrocarbons, chlorinated solvents and other organics. NICOLE (Network on Industrially Contaminated Land in Europe) compares existing protocols and develops and tests a general framework for Europe-wide application. A UK guidance document will shortly be published by the Environment Agency.

In conclusion, we know that

- the properties of most organic contaminants require long-term, cost-effective treatment processes
- natural attenuation happens
- monitoring natural attenuation can be effective in risk-based evaluations either in isolation or as part of a wider programme and
- appropriate monitoring is required.

However, there are several things we still need. These include:

- 'operating windows' for natural attenuation. In order for the application of case histories to be useful we require information from a wider range of geological conditions, soil and groundwater, as well as contaminants. Constraints such as source areas, anaerobic benzene degradation and bioavailability must also be better understood
- an understanding of long-term stability of natural attenuation especially for chlorinated solvents
- some aspects of the microbiology must be better understood
- monitoring practices over the long-term must be of a high quality.

Biological remediation methods

John Lapinskas & Lionel Barnes**,*
**DG Environmental Ltd, Pinnacle House, 23-26 St Dunstan's Hill, London EC3R 8HL*
*** 164 Sandyhurst Lane, Ashford, Kent TN25 4NX*

The accelerated growth of the petrochemical industry in the twentieth century has generated a wide variety of anthropogenic compounds. During the last decade, interest in the application of biological methods for remediation of both organic and inorganic wastes in soil and groundwater has increased markedly, especially the microbiological treatment of petroleum hydrocarbon contamination.

Bioremediation of organic contaminants is the technique by which bacteria and/or fungi are used to eliminate contamination through a process of oxidative mineralisation. Decontamination proceeds as the microbes utilise the hydrocarbon contaminants as a substrate or food source. In the presence of the appropriate nutrient concentration, bioremediation may proceed rapidly in both aerobic and anaerobic environments.

"... during the last decade, interest in the application of biological methods for remediation of both organic and inorganic wastes in soil and groundwater has increased markedly, especially the microbiological treatment of petroleum hydrocarbon contamination ..."

A biofeasibility study should be carried out in order to assess if bioremediation is likely to be successful. This requires laboratory investigations to determine how various combinations of bacterial and fungal strains degrade the contaminant of concern. By subjecting groundwater or soil to varying conditions of inoculum, nutrient formulations and co-substrates, a degradation profile of the hydrocarbon can be charted over the course of time. The optimum degradation rate depends on the presence of suitable microbes, together with environment and site conditions. Microbes need favourable conditions for respiration, substrate utilisation, energy generation, growth and reproduction. For example an oil spill may be rich in carbon, but lack other essentials such as nitrogen and phosphorus necessary for microbial metabolism. Oxygen and temperature are also important. Site conditions will determine whether the bacterium already living in the soil can be utilised to degrade the hydrocarbon contamination (i.e. biostimulation) or whether other strains have to be cultured prior to on-site application and inoculation (i.e. bioaugmentation).

Contaminated soil can be treated by ex situ or in situ methods. The ex situ method involves excavation of the soil, which is placed on a plastic lined biotreatment bed (which prevents leaching down into the soil below). This has the advantage that the environment can be controlled and remediation measured. The disadvantages are the costs of excavation, plastic liner, drainage, aeration, irrigation etc; the requirement for a large treatment area; and a remediation period of three to nine months. Treating soil in situ can be advantageous where excavation is impossible and it also cuts cost. Nutrient and microorganisms are carried into contact with the contaminants by water, which is pumped out and contained to avoid the spread of contamination. The hydrocarbons are collected and the water recycled until the site is deemed clean. This method requires suitable geological conditions so that the water can percolate through the soil and there is no blockage preventing flow. The in situ method may take one or two years depending on concentration of contaminants and the lateral extent of the contamination.

Inorganic material treated by bioremediation includes degradable inorganics (cyanides, thiocyanates, ammonia and nitrate), gaseous inorganics (hydrogen, sulphide and sulphur dioxide) and non-degradable inorganics (metals and non-metals).

Degradable inorganic contaminants such as cyanides and thiocyanates are associated with gas works, metal processing and mining. An aerobic process is used at Homestake Mine (South Dakota) involving a rotating biological contractor in which contaminated influent is washed across biomass-coated discs and effluent is taken away. Ammonia and nitrate are associated with agriculture and mining and treated by aerobic (nitrification) or anaerobic (denitrification) processes.

Gaseous inorganic contaminants such as hydrogen sulphide and sulphur dioxide are derived from oil refining, natural gas and flue gasses. The aerobic process has chemical and biological steps, but the anaerobic process involves bioremediation only.

An example of non-degradable inorganic contamination results from lead smelting producing sulphuric slag. Chemical oxidation reduces pH from 12 to 7 at which point biological methods can be used to produce water and slurry which can be removed from the environment.

"... a biofeasibility study should be carried out in order to assess if bioremediation is likely to be successful. This requires laboratory investigations to determine how various combinations of bacterial and fungal strains degrade the contaminant of concern ..."

Microbial removal of heavy metals and sulphate (from aqueous streams related to refining) using sulphate reducing bacteria, has been carried out by a number of companies including Budelco bv. Bioremediation required the presence of nutrients (C/N/P), a suitable pH (5–9), reducing conditions, a period of several hours for liquid residence and suitable temperature. Carbon is used as a substrate for organism growth and food source. A pilot project was carried out with a small plant reactor and organisms from a local pond and it took a just few days to get the plant working. It proved the viability of using sulphate reducing bacteria; that the technology was correct and could be scaled up; and there was just a short start-up time. Continuous operation for six months was demonstrated and the residence time in the process was shorter than the design value. Only the time required for the sulphide sludge to settle limits the process. Based on the findings of the pilot study a commercial plant was built. This method has applications in a number of areas including groundwater, land run-off, process streams, process effluents and acid mine drainage. For agricultural and industrial waste this method proved cheap and reliable.

aluminium	copper	scandium
antimony	gallium	silver
arsenic	indium	tellurium
beryllium	iron	thallium
bismuth	lanthanum	tin
cadmium	lead	titanium
cerium	mercury	vanadium
chromium	nickel	zinc
cobalt	selenium	zirconium

Elements removed by sulphate reducing bacteria.

Risk assessment techniques

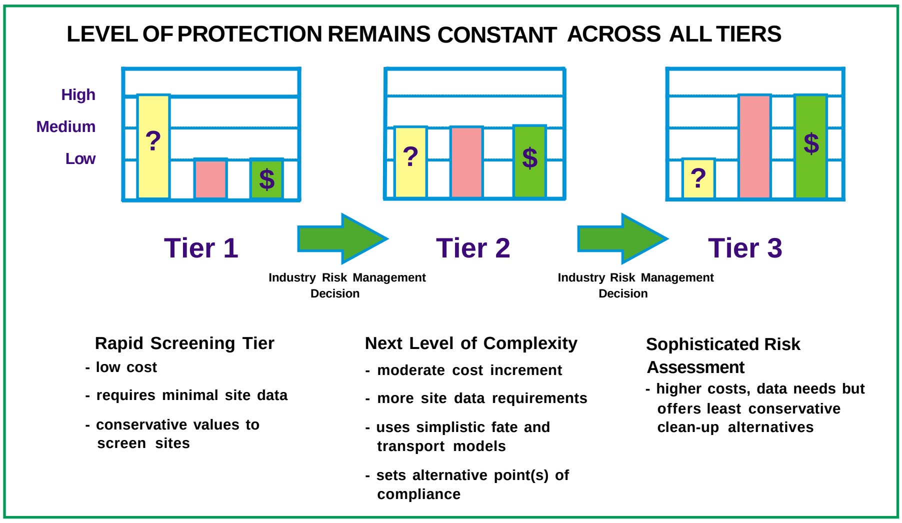
Judith Petts, Tom Mitchell** & Mary Harris***,*
** Centre for Environmental Research and Technology, The University of Birmingham, Edgbaston, Birmingham B15 2TT*
***Technical Leader Water Management, Shell Research Ltd, Health, Safety & Environmental Dept., Shell Research & Technology Centre, Thornton, P O Box 1, Chester CH1 3SH*
****Monitor Environmental Consultants, Blakelands House, 400 Aldridge Road, Great Barr, Birmingham B44 8BH*

There were four main aims to this workshop. The first was to understand the principles and procedures of risk assessment. The second aim was to find out what risk assessment tools are available, which are generally used and by whom. Thirdly, what risk assessment tools are required (models and guidance) and finally how can we communicate the results, methods and interpretation?

Risk assessment is important:

- as a legal requirement
- in determining what redevelopment can take place on a site
- in determining what can be investigated and
- in considering what remediation techniques are appropriate.

The process needs a methodology scaled to the problem along with identification of contamination sites, classification of the problem and agreement between all concerned about the solutions. Methods used should be standard. However, at the moment, guidance values are often incorrectly used, arbitrary or inappropriate e.g. by using Dutch or Canadian values in a UK setting.



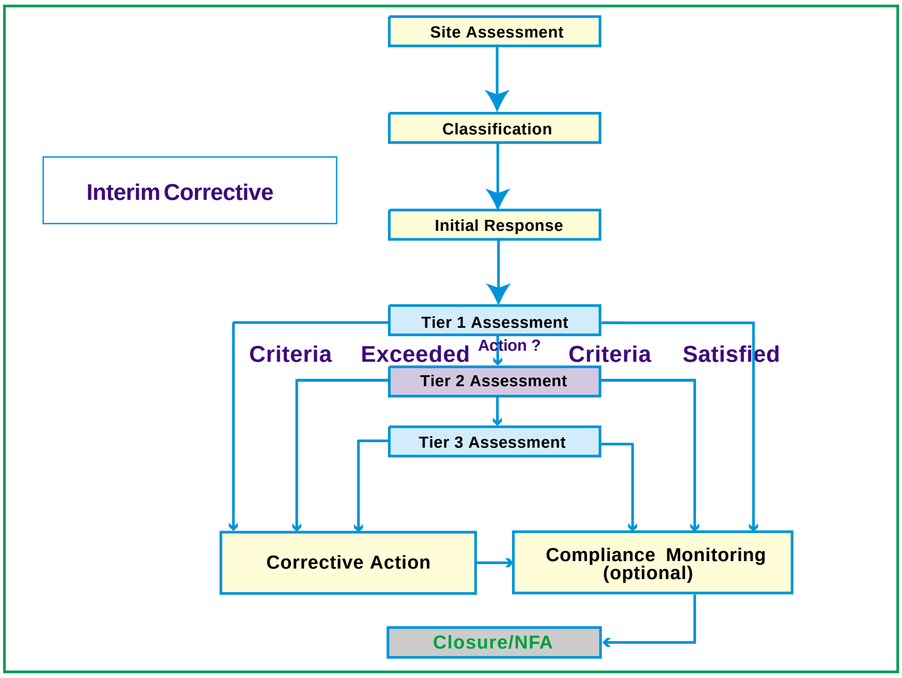
Tom Mitchell

The three tiers of the RBCA.

The RBCA (risk-based corrective action) is an integrated process that aims to give practical guidance for integrating traditional corrective action with exposure and risk assessment activities. It is a three-tiered framework that allows decisions to be made at the initial level, including whether to carry out a 'tier upgrade' to a second or third level. These use site specific data to help make better informed decisions.

The role of a conceptual model is to keep the project focussed on solving a specific problem so that data are not collected for collection sake. A conceptual model describes the characteristics and dynamics of the physical system (geology, hydrogeology, physical and chemical processes, historical records and photographs, etc.) and consolidates site and regional data into a set of assumptions and concepts that can be evaluated quantitatively. It requires the collection and analysis of pertinent system data, which must be of appropriate quality and quantity. Appropriate field sampling methods must be undertaken and there must be an understanding of why the data is required and how it can be interpreted. The conceptual model requires an understanding or working hypothesis of the source area such as soil, ground water, etc., mechanisms of movement such as leaching, vapour, and so on, recipients of the contaminants e.g. residents, surface water and the exposure mechanism such as inhalation, ingestion etc. There is also the need for a basic understanding of the concentration of the contaminants on a site, their distribution, factors affecting transportation or migration and their potential to reach a receptor.

In conclusion, it became evident during the workshop, that personnel involved in risk assessment need to reach a consensus on the correct tools to be used, the methods that were applicable to the task, how to interpret the results and how to reach appropriate decisions. Models are misused or used in a random manner causing concern to many who carry out risk assessments, and it was felt that training is essential. New and existing models are needed to link together the various elements of risk assessment. The most cost-effective approach to decision making is the tiered approach which focuses on problems. Finally the link with users is important and they need to be asked again what tools they require and why.



Tom Mitchell

The RBCA framework.

Verification of treatment

Alwyn Hart, Environment Agency, 10 Warwick Road, Olton, Solihull, B92 7HX

Investigation and remediation of land contamination depends on the effective application of a wide range of skills and techniques. Decisions that must be made for an individual site rely on appropriate sampling and chemical analysis of soils and waters. It is this measured data of pollutant amounts or concentrations that must form the basis of verifying whether the selected treatment has been successful and has met the performance targets originally envisaged. In the context of the management of risk it is these data which allow us to assess whether the risk has been reduced to a level to make the site suitable for use. However, soil is rarely homogenous, particularly in the case of former industrial sites, which may contain generations of plant, areas of made ground and mixtures of contaminants. Sampling, analysis and the interpretation of results for subsequent verification of treatment efficacy, are major challenges for regulators.

For some years the description of land as 'contaminated' and hence potentially in need of remediation was ill defined and hence open to interpretation. However, Part IIA of the Environmental Protection Act 1990 defines contaminated land 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'. Harm is defined as 'harm to the health of living organisms or other interference with the ecological systems of which they form a part and in the case of man includes harm to his property'. The policy on contaminated land requires remedial action where 'unacceptable actual or potential risks to health or the environment exist' with the aim of making land suitable for use. The Environment Agency is committed to contributing to the sustainable development of land and the use of appropriate remedial methods through a sound assessment of the risks, costs and benefits of treatments.

The starting point for verifying whether a treatment has been successful is normally the initial designation that an area contains contaminants at concentrations in excess of the desired level. An early stage in making this judgement is often the sampling to obtain a representative value of contaminant concentration. It may also be wise to gather some information on how the contaminant is spatially distributed.

The efficacy of the treatment is most often judged by the use of conventional bulk property analytical procedures. Samples are processed at intervals and any decrease in contaminant concentration over time is calculated. A proportion of the decrease (often all of it) is then assigned, perhaps erroneously, to the effect of treatment. However, assessment of the effectiveness is normally susceptible to the same sampling and analytical errors as intial determinations of contaminant concetration on the site. Mechanisms must be sought to reduce these errors and minimise the problems which they can cause.

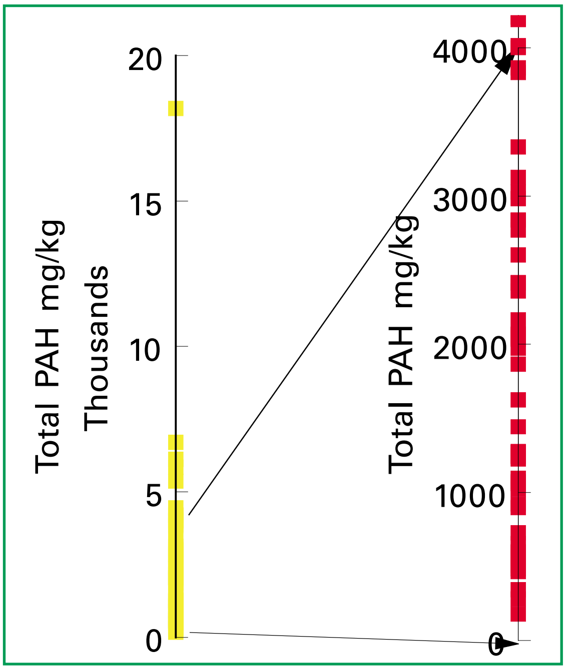
There may be problems in establishing the initial contaminant concentration prior to the start of treatment. Most site investigation strategies typically and rightly focus on the detection of 'hot-spots'. However, this approach is unlikely to provide all the information required at the start of a treatment process. Once a treatment is deemed necessary, it is important that the data are reviewed and an appropriate sampling strategy implemented. This will almost certainly involve a further sampling and analysis. It should be remembered that 'large static heaps of a heterogenous product cannot be sampled satisfactorily' (Laboratory of the Government Chemist).

It is vital to select and standardise analytical methods to be used throughout treatment. Unusual or inconsistent analytical methods may present a major handicap to the final assessment of the treatment. For example, the independent validation report on an early UK bioremediation project, states that 'direct comparison of before and after results is almost impossible' and 'the results...demonstrate compliance with the DoE's post-treatment requirements. It cannot be said though, that there has been a real reduction in (contaminant) levels' (Lancashire County Analyst). Standardisation of methods and the use of quality standards has allowed continual improvement in analytical performance. Even so, significant differences in analyses from separate laboratories are likely, as shown by competency exercises organised by BG plc.

Case studies showing independent validation or verification of treatments are not common for the UK. This is not surprising, since the costs of additional sampling and analysis plus specialist interpretation are high. Nevertheless, it is also recognised that the lack of high quality case study information, particularly for completely new treatment methods, has been one factor limiting the uptake of new techniques. The proposed CLAIRE initiative to provide field sites may go some way to overcoming this problem.

Remediation of contaminated sites and the manner in which it is carried out, should not be considered in isolation from other environmental factors. Therefore, in discharging its duties under Section 4(3) of the Environment Act 1995, the Environment Agency considers the remediation process in the context of sustainable development, which can be defined as '..development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Brundtland Report, *Our Common Future*, 1987). Verification of treatment will, therefore, need ways to measure the wider environmental issues around a treatment method and thus its overall environmental merit. This in turn implies a long term perspective in land remediation with consideration of intensive and/or extensive remedial techniques and the implications of temporary solutions that do not reduce the inherent toxicity of source contamination.

In summary, verification of treatment is likely to become an increasingly important aim for regulators involved with land remediation, so that land owners, buyers, regulators and the general public have full confidence in the re-use of former industrial sites. It is also important from a regulatory perspective that treatments which do not fulfil their objectives or which cause additional, perhaps unforeseen, environmental problems are identified early and that lessons are learned. Both sampling and analysis methods are key to the validation and verification of any treatment process as they provide the basic data for subsequent interpretation. Regulators will need to have confidence in these aspects of a remedial treatment.



Two samples from a relatively small (approximately 100m^3) volume of gasworks soil suggested contaminant concentrations of around 6000 mg/kg. Analysis of a further 54 samples reveals the very heterogenous nature of the soil and that the earlier samples were not representative. Unless the variability of soil which is to be treated is assessed the inherent variation may be confused with the treatment effects.

Alwyn Hart, Environment Agency

An overview of remediation technologies

Paul Bardos, r[3] Environmental Technology Ltd, Ware, Hertfordshire, SG12 0AA

Remedial options generally fall into one of several categories. One option may be the removal of the contamination off site for treatment, disposal or landfill. Containment may be another option, to prevent migration from a site or to store the contaminants. Rehabilitation may be possible in order to bring a site back into use, even though the contamination cannot be treated or contained for technical or economic reasons. A further option is a treatment based response in which the contaminants are destroyed, removed or detoxified.

Treatment processes treat contaminants in a variety of materials. These materials might include groundwater, soil, fill, debris, site refuse, non-aqueous fluids, tars or sludges. The type of treatment and its success will depend on the nature of the material treated and the type of contamination. Contaminant properties affecting treatment include not just the chemical types present, but their concentration, their source and their age.

> ***"... why is remedial action necessary? Typically the answer is to achieve redevelopment, protect human health, protect the environment or limit potential liabilities ..."***

Treatment technologies are usually described in the context of their process category, e.g. biological, chemical, solidification/stabilisation, physical and thermal.

Biological treatment is carried out in several ways:

1 A compound may be decomposed by aerobic or anaerobic microorganisms in the soil such as bacteria, fungi etc. (i.e. biodegradation).

2 Contaminants may be converted to less toxic or less mobile forms, for example where micro-organisms generate phosphate ions which precipitate heavy metals as insoluble complexes (i.e. biological transformation).

3 Some organisms, e.g. plants and algae, can accumulate organic and inorganic contaminants within their tissue and this can be harvested later (biological accumulation).

4 In some biological processes contaminants enter solution which can then be separated from the contaminated soil and then recovered or destroyed (mobilisation of contaminants).

Chemical treatments destroy, fix or concentrate toxic contaminants by chemical reactions. Many methods have been devised to treat groundwater and effluents or emissions from soil treatment.

1 Toxic organic compounds may be oxidised increasing the chemical valency of contaminants.

2 The chemical valency of toxic contaminants may also be decreased using chemical reagents, so that, for example, chromium (VI) is reduced to the less toxic and less mobile chromium (III) (reduction).

3 Contaminants may be removed by precipitation.

4 Contaminants may be extracted or leached using acids, alkalis, surfactants and organic solvents so they can be collected, concentrated and treated.

Physical treatments separate contaminants from the soil by exploiting physical differences such as volatility or density. In some cases electrolysis, electro-osmosis and electrophoresis can be used to remove contaminants.

Solidification is where the contaminated material is mixed with reagent which allows it to set hard as granules or in a monolithic mass. Solidification may be accompanied by stabilisation where chemical reactions render contaminant species less mobile and/or bind them into the solidification matrix.

Thermal treatment removes, destroys or immobilises soil contaminants.

What remediation approaches should be taken? Risk management is the first concern in remediation, but environmental impact of the remedial process must also be considered, in particular preventing the spread of the contamination and increasing the supply of clean soil and water. Issues such as public acceptance, economic and political impact also have to be recognised.

Why is remedial action necessary? Typically the answer is to achieve redevelopment, protect human health, protect the environment or limit potential liabilities. Thus remediation seeks to establish suitable geotechnical conditions for redevelopment, treating contamination, preventing transfer of pollutants and limiting environmental costs.

Depending on the scale and type of contamination, site remediation may require several methods of treatment, not just one. On a single site several remediation operations may go on at once. This requires careful management to achieve best effectiveness and minimum cost and environmental impact. Some remedial treatments may be intensive, taking place for short periods, but be financially or environmentally costly. Methods that operate for longer periods may turn out to be lower in maintenance, cost and energy needs.

The outcome of some remedial treatments may result in the destruction of the contaminants by biological and/or chemical degradation. The outcome of others is removal by mobilisation and recapture (e.g. leaching), concentration and harvesting (e.g. physical separation). For a third group the outcome is stabilistaion where the contaminant remains in place but is made less mobile or less toxic by biological, chemical and /or physical processes.

Site assessment, sampling and analysis

John Thompson, Consultant Scientist & Technologist, 49 Hazel Drive, Armitage, Rugeley, Staffordshire WS15 4TZ

The aim of this workshop was to discuss the design of site investigations to ensure that they are appropriate to the particular site and sources of contamination, using cost effective techniques and protocols. This involved three main issues: sampling strategies, data appraisal and definition of appropriate output.

Field tests with chemical, physico-chemical, biochemical or biological measurement systems have different roles to play in assessment of contaminated land:

- in initial site surveys to assist in planning more detailed site surveys
- in detailed site surveys, using samples from trial pits or boreholes
- in assessing in situ remediation processes
- in checking soils being taken for off-site remediation or disposal
- in field testing on arrival at a landfill (draft EU Landfill Directive), and
- for use in initial COSHH assessment of samples arriving at a laboratory for detailed assays.

Due to the high cost of laboratory assays, few samples are usually collected. For this reason considerable care must be exercised in designing a sampling strategy in order to give an accurate picture of the three-dimensional distribution of contaminants on the site. Uncertainties resulting from assays, sampling techniques and sample preparation should be estimated. Without the assessment of uncertainty, credibility of the investigation may be put in doubt. The overall, combined uncertainty may be as great as 50–200%. Soils may be incorrectly classed as contaminated as a result of these tests. False positives and false negatives can both lead to costly problems and disputes.

Low precision (compared to laboratory assays) testing kits may be more cost effective with an appropriately designed sampling strategy. More samples can be taken at a lower cost so a more reliable assessment of uncertainty can be made despite the lower precision of each individual test. The uncertainty of the tests can be estimated by taking duplicate samples.

The use of field testing in contaminated land assessment could be accredited provided that the appropriate standard operating procedures and QA/QC protocols were adhered to in site surveys of specific types. It is no different from accrediting laboratory procedures. Protocols would achieve consis-

continued over . . . .

tency in sampling and analysis, for establishing criteria for compliance with acceptable and appropriate contamination thresholds, and the extent and spatial distribution of contamination. Uncertainties should include variability in field sampling methods together with estimates of bulk sample heterogeneity, subsampling, preparation, and analysis within and between laboratories and staff. The VAM (valid analytical methods) programme is a joint DTI/Laboratory of the Government Chemist initiative to develop accreditation and proficiency testing.

"... due to the high cost of laboratory assays, few samples are usually collected. For this reason considerable care must be exercised in designing a sampling strategy in order to give an accurate picture of the three-dimensional distribution of contaminants on the site ..."

During the workshop several key outcomes were identified:

- there must be clear objectives
- a holistic approach should be taken
- a phased approach to site assessment should be carried out — an iterative process that is continually validated
- desk top studies are appropriate in order to examine all sources of data and including the development of a conceptual model
- field investigations are necessary, and should include an initial (walk over) survey to help the development of a more detailed sampling strategy
- there should be a balance between field tests and laboratory assays
- it is vital that staff are appropriately trained
- audit trails allow errors in sampling, preparation and analysis to be tracked
- there must be confidence in the results and the appropriate use of statistics feeds back into realistic objectives
- there is a COSHH element in planning and execution at all stages
- targets should be agreed with regulators, including receptors and trigger levels.

In conclusion:

1. Field tests were seen to be an important tool for site investigation. They allow a large number of samples to be taken at reasonable cost. However, they need to be supported by an appropriate calibration and quality management regime.
2. There is a need to understand the significance of the data and its interpretation relative to objectives.
3. It is important to understand elements of bias introduced by sampling and laboratory procedures and that one can easily estimate relative bias.

Groundwater and contaminants risk modelling options

Martyn Lambson & David Hall**,*
**BP International Ltd, Research & Engineering Centre, Chertsey Road, Sunbury on Thames, Middlesex TW16 7LN*
***Golder Associates (UK) Ltd, Landmere Lane, Edwalton, Nottingham NG12 4DG*

This workshop on transport modelling of groundwater contaminants concentrated on two models, ConSim (contaminated land simulation/risk assessment model), and RISC (Risk Integrated Software for Cleanup). They are just two of a large number of computerised models available. They are intended to be useful, but the user needs to understand the conceptual model, the basis of the data being entered and the toxicology. All models need to be defensible and transparent, both to the owners and the regulators.

ConSim, which has been developed on behalf of the Environment Agency, is intended to assess the impact of contaminated land on groundwater. It is not a human health risk model. The model carries out Monte Carlo analysis and addresses data uncertainty. It uses a multi-stage assessment approach. Level 1 is a synthetic leach test or will calculate concentrations based on measured soil contamination. Level 2 addresses vadose zone migration, and the assessment looks at the downward migration of contaminants. The model uses a constant source term and includes retardation and biodegradation, both of which can be switched either on or off. Unlike many models, ConSim also takes into account background concentrations.

Level 3 runs a Domenico 3-D advection and dispersion model which allows assessment of receptors off the centre line for hydraulic flow. Calculated concentrations can be assessed with respect to exceeding given standards. Each level requires more data and thus becomes more expensive.

ConSim is a simple model which assumes simple hydrogeology and geology. It allows uncertainty to be expressed, though it was stressed during the workshop, that a 'good guess was no substitute for good data'. The model does provide a simple method for defining what is important.

RISC was developed mainly for use in North America, although it has been used elsewhere in the world. The model has five steps of which the first three correspond to ConSim and the final two cover receptor risk/exposure pathways. It is still evolving with an ecological criteria package soon to be added. The model is a human health risk model that contains exposure scenarios and gives cleanup levels at sites. It works for both soils and groundwater and contains data on 82 chemicals: its interactive nature means that the database can be added to if the user has appropriate data. For multi-component hydrocarbons, the carcinogens such as benzene, are taken out and handled explicitly while the other components are handled as surrogates, e.g. as carbon groups.

RISC has a screening model based on risk-based corrective action (RBCA). It allows risks from different exposure routes to be calculated. The model, which takes a tiered approach, uses proven fate and transport models for the vadose zone, saturated zone and volatilisation from groundwater to indoor/outdoor air. It uses a depleted source term, and can be run either with single values or as a Monte Carlo probabilistic model.

The main points of the discussion included:-

1. Human health is the main driver of risk assessment.
2. RBCA is a framework to be used as a screen and that decisions on exposure pathways should be included depending on where the model is being used.
3. Comparison was made between ConSim and other models available. ConSim, for example, differs from LandSim (landfill simulation/risk assessment model) in including biodegradation, uses a different advection-dispersal model allowing concentrations off the centre line to be determined and has several hard standards programmed in. It differs from other models by including groundwater as a pathway, but as it was not designed for hydrocarbons (it is more applicable to heavy metals) it does not include a depleting source term. It is a simple tool that gives a feel for the issues when dealing with contaminated land sites of complex geology, poor data etc., but more complex modelling may be required to establish the 'real' answer. Unfortunately most people use models as 'black boxes' giving definitive answers so education is very important.
4. The internal modules of both models had been verified, but validation was difficult particularly due to problems associated with establishing site conditions at time zero.

The conclusions of the workshop were that:

- several models and techniques are available
- a tiered approach is preferable
- there is a need to understand model limitations
- and the level of risk must be balanced with exposure scenario.

Groundwater contamination risk modelling is not an exact science.

Contaminated land sampling and analysis

Steve Wallace, Lattice Property Holdings, Wharf Lane, Solihull B91 2JP

Analyte	No. of laboratories	Minimum value (mg/kg)	Maximum value (mg/kg	Mean value (mg/kg)
Total PAH	17	15	365	228
Total cyanide	19	80	8233	1270
Sulphate	20	2703	6173	3598
Lead	19	77	134	102
Arsenic	18	2	31	16

There are both technical and business issues at play with regard to the quality of analytical data procured on contaminated land projects. Technical issues are related to such aspects as the size of the programme of investigation and remediation. There may be a time lag between investigation and remediation, individual projects can last many months and there is a requirement for long term monitoring. Business issues are concerned with the prioritised action over the portfolio together with its value and sale price, confidence that liabilities have been addressed before disposal and the confidence of third parties including regulators, purchasers and tenants.

It is of fundamental importance that accuracy is maintained in the analysis of contaminated land. However when reference material has been sent to a number of laboratories for analysis, widely divergent results have been returned.

Unreliable analysis for site investigations will result in an incorrect assessment of risk. In terms of remediation, errors of, for example, 50% in analysis can give +400% to –70% error in volume and also grossly unreliable validation. In other words, the cost of mistakes is much higher than the cost of procuring good data. The methods used in analysis may also give rise to error as shown in the example for cyanide and the impact of the analytical error on remediation costs. A method that might work for one soil matrix might not be fit for purpose for another.

It is vital that the correct methods of analysis are used. It is also evident that it is very difficult to find a reliable laboratory and accreditation is not, on its own, a reliable enough indication of fit for purpose. The lack of harmonisation of sampling and analysis protocols has resulted in laboratories producing widely different results from the same samples.

Customers require confidence in the laboratory analysis they commission and the CONTEST scheme aims to provide this. Four interlab exercises are carried out each year on a range of analytes. There is a statistical assessment of results, but no constraints on methods. As a result, selected individual laboratories are improving, but the data recorded by the overall scheme are not.

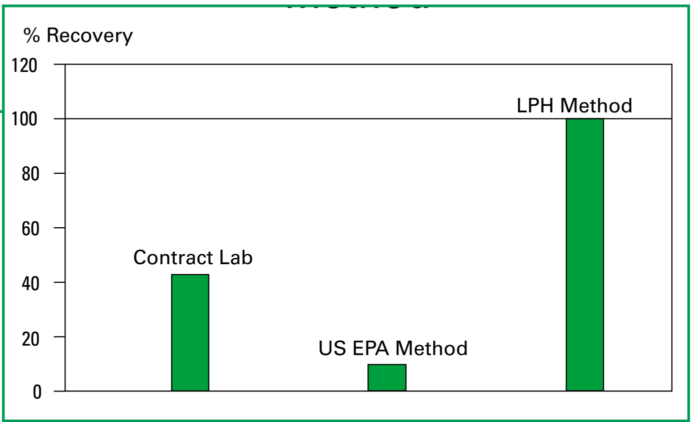
The validation process of Lattice Property (formerly BG Property) requires proficiency testing every six months. It is carried out on gasworks reference materials and standard analytical methods. A laboratory audit is carried out, a critical review is undertaken and satisfactory performance is mandatory. Proficiency testing is managed by Advantica Technology (formerly BG Technology) and 31 laboratories participated in the last exercise. The data are assessed using robust statistics and the scheme is operated on a pass/fail basis (approximately 60% pass at present). Six years of data now exist for many laboratories in the scheme and the pass/fail performance is monitored with time.

Pass rate performance	No. of Labs
100%	25
51-99%	25
26-50%	29
0-25%	21

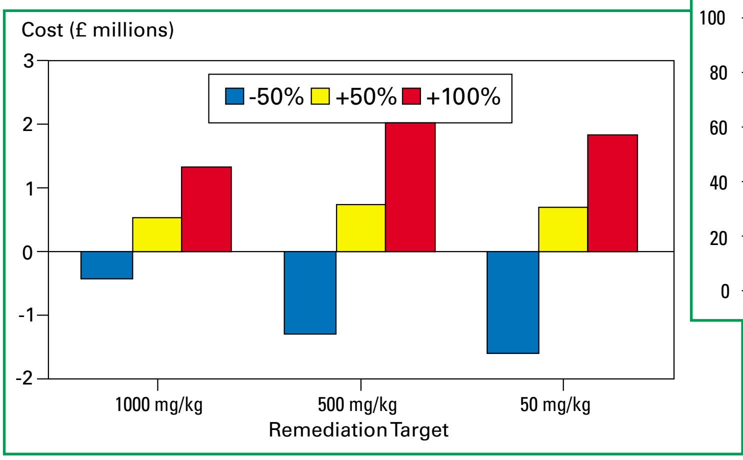
Change is desirable both outside and inside the laboratories. Outside the laboratories, it is evident that environmental consultants are often poor at analytical chemistry, both in procurement and quality assurance. A method of policing quality seems appropriate, but who would carry out this role? The larger players can look after themselves, but the smaller organisations cannot. Laboratories need to take a more professional stance in their business activities and many are deficient in routine quality assurance and in the QA of their reports. CONTEST is working towards performance ranking, standardised reporting, datum results and method discrediting. There must be a standardised validation protocol (standard methods are not validated methods nor fit for purpose) and there should be CRM's for important analytes. Accreditation needs to focus more on the end user and recognise that there is currently no useful minimum standard and that industry should encourage greater dialogue between consultants and laboratories.

In conclusion, it is possible to get quality contaminated land data, the quality of the product is improving and awareness is increasing. However more needs to be done to challenge the output.

NB Since the workshop the EA have introduced a new quality system for contaminated land analysis. This is still being implemented but should enhance the quality of data being generated.



Steve Wallace



Steve Wallace

Above *Variation in cyanide results with method.*

Left *Impact of analytical error on remediation costs (£4 million base case).*