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Investigating Contaminated land

Although contaminated land does not receive quite the same public attention as other environmental issues, it is an important area of applied environmental science and provides employment to a significant number of professionals, in both the public and private sectors. The effective regulation and management of the risks from historic soil pollution are relevant to multiple stakeholders, and its costs and other impacts can affect government bodies, property developers, industrial firms and private individuals. Its complex legal framework is matched by equally complex technical assessment procedures and there is the possibility that politicians, the public and the press can take a keen interest in the decision-making relating to specific land-contamination cases.

Commercial, public health and environmental imperatives need to be balanced against this potentially high-pressure backdrop, so that brownfield sites can continue to be used for re-development (as with the Olympic Park) and the pollution legacy of past industrial activities is dealt with appropriately (as at Helpston). With 'risk' being the key watchword (since there are very few examples of actual harm being caused by contaminated land), there is a need for the detailed modelling of contaminant behaviour and toxicity to underpin land contamination risk assessments, in as realistic and pragmatic a manner as possible. Similarly, as landfill costs continue to escalate, and the needs of sustainable remediation are recognised, the field of remedial engineering requires innovative solutions to be brought to bear when cleaning up contaminated land, so that it is carried out as cost-effectively as possible.

This issue explores some of the aspects referred to above and provides an overview of important topics within the contaminated land arena. Recent changes to government guidance are explained in detail and various facets of land contamination risk assessment, including the analysis of uncertainty, are reviewed. Currently available techniques for remediating sites are highlighted, as are the principles of sustainable remediation. Case study material is also provided, while the UK's contaminated land regulation is discussed in a thought-provoking manner.

"Commercial, public health and environmental imperatives need to be balanced against this potentially high-pressure backdrop, so that brownfield sites can continue to be used for re-development"

Overall, this issue will provide information which is of use to both experienced practitioners and pre- or early-career environmental scientists. The work of a contaminated land professional is unlikely to be performed in exotic locations, but it does require the application of environmental science in a rigorous and practical way, so that the work can continue to make a real and long-lasting contribution towards a cleaner and better environment.

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Remediation & Litigation In a Contaminated Land

Steve McNab and **Carolina Varga** take a look at the landscape of contamination in the UK.

It was Pandemonium but a great showcase for the remediation skill of the UK. The gloomy industrial revolution – depicted for billions by Danny Boyle at the opening ceremony of the 2012 Olympic Games – with its belching chimney stacks reminded viewers of Britain's long industrial legacy. Modern day planners would baulk at the idea of allowing the village green to be torn up to make way for factories and stacks (unless supported by an acceptably loaded s.106 obligation, of course), but that is what viewers witnessed in post-industrial Stratford. The real lesson we can surely take from these scenes is that no matter the perpetrators of historic pollution, the UK's leading in situ remediation skills can ensure that industrial-legacy contamination can be safely removed such that the land can be made suitable for sparkly sports tracks. Anthony Futughe's article on **Page 52** describes some of the more novel in situ remediation strategies that are available, although few are as instantly effective as Boyle exhibited.

As we will read in the article from Fenton & McNicholas on **Page 32** you can clearly get a lot of remediation out of a mere £11bn.

This introduction provides some context and a recap on some of the key features of the primary regime for dealing with contaminated land in England and Wales, the Contaminated Land Regime (Part 2A of the EPA 1990, the "CLR") which has been spruced up (a little) with the issuing in April 2012 of new guidance on how the regime is to be applied.

Table 1 identifies additional legal regimes that provide legal triggers to environmental liability for contamination. These can result in investigation and

Photo credit Matt Lancashire

Contaminated Land Regime (Part 2A of the Environmental Protection Act 1990)	A risk based regime: land is "contaminated" where the enforcing authority believes that significant harm is being caused to the environment, where there is a significant possibility of significant harm, or where significant pollution of controlled waters is being caused or is likely to be caused. The primary regime for dealing with historic contamination no matter when in time the contamination occurred. For "special sites" the regulator will be the EA. Remediation must be to a standard such that the land is suitable for its current use.
Planning (Town and Country Planning Act 1990 and related legislation)	The planning authority should attach conditions, or enter into planning obligations to ensure that any unacceptable risks to human health, buildings and the environment from contamination are identified and properly dealt with as part of any redevelopment. Whoever buys land subject to a s.106 agreement will become responsible for fulfilling any aftercare obligations. Specific aftercare regimes apply to certain high risk activities. Remediation must be to a standard such that the land is suitable for its proposed end use.
Water Pollution (Environmental Permitting Regulations 2010)	It is an offence to cause or knowingly permit a water discharge activity unless you are complying with an environmental permit or exemption.
Works Notice Procedure (section 161 & 162 of the Water Resources Act)	A works notice may be served where it appears to the Environment Agency that poisonous, noxious or polluting matter or any solid waste matter is likely to enter into, is or has been present in any controlled water. The notice may be served on any person who either (a) caused or knowingly permitted the matter in question to be present at a place from which it is likely to enter controlled waters or (b) caused or knowingly permitted the matter to be present in any controlled waters. The works notice may require removal, remedy or mitigation of the pollution, to restore the waters and/or to prevent further pollution entering the controlled waters. EA may take steps to remediate and charge the responsible person for the EA's costs. Similar powers apply where there is a threat to the environmental objectives of a water body such that its chemical or ecological status is not good. These powers do not require works to achieve a specific standard.
Environmental Damage (Prevention and Remediation) Regulations 2009	The regulations implementing the Environmental Liability Directive require operators causing environmental damage to remedy that damage and, where there is a risk of damage, to prevent that risk from occurring. Remediation of environmental damage to water is mostly regulated by the EA. Liability can be strict for certain higher risk activities. Standard of remediation varies depending on whether it's land or natural resources (water, protected species or habitats). Does not apply to historic contamination (i.e. before March 2009)
Waste Management (s.73, s.33 and s.34 of the Environmental Protection Act 1990)	Section 34 imposes a duty of care on all persons who deal with controlled waste. Depositing, keeping, treating or storing waste without a permit or in a manner that is likely to cause harm to the environment or prevent the escape of waste is a criminal offence.
Common law	Neighbours or down-gradient users of groundwater could have an action in damages against a site owner in tort, nuisance or the rule in Rylands & Fletcher, e.g. for negligent storage and treatment of waste or nuisance caused by their use of land. Third parties could seek to assert riparian rights over the downstream water which has been impacted or for personal injury or property damage.
Statutory Nuisance (s.79 and s.80 Environmental Protection Act 1990)	Local authorities may serve an abatement notice for any statutory nuisances which includes any accumulation or deposit which is prejudiced to health or a nuisance.
Health and safety (Health and Safety at Work Act 1974 and related legislation)	All reasonably practicable steps are required to be taken to protect employees and the general public. This includes risks to neighbours (e.g. soil gas migration) or redevelopment workers (e.g. asbestos exposure). Failure to comply with this general duty and other more specific duties can give risk to criminal sanction (fines and jail).

▲ **Table 1: Key legal triggers to environmental liability for pollution and contamination** remedial costs, compensation awards, civil penalties, criminal fines and in extreme circumstances, loss of liberty and jail for directors and other responsible persons. The author has experience of regulators invoking or threatening to invoke all of those regimes in cases involving contaminated land. Depending on the specific circumstances there will often be more than one regime that can be applied and different enforcement powers available, especially so in cases involving groundwater. Finally, we briefly consider how on a transactional basis such environmental risks can be most effectively managed.

THE CONTAMINATED LAND REGIME

The broad objective of the CLR, as stated in the Guidance, is to "strike a reasonable balance between identifying and removing unacceptable risks to human health and the environment whilst ensuring that the burdens faced by individuals, companies and society as a whole are proportionate, manageable and sustainable." The comments by Valerie Fogleman in her article at [**Page 55**] provide a valid critique of the CLR, a complex framework for legal and technical practitioners with both practical, pragmatic features and some quite serious flaws. ERM's Phil Crowcroft described Part 2A as "an over-decorated Christmas tree, with too many baubles and too much tinsel."

The CLR has certainly had some successes, both in use and threat of use but it is far from straightforward to navigate and enforce (whichever side of the fence you sit on) and has too often been used as a sledgehammer to crack a nut.

Government intention is to "help drive market solutions"[2] whereby contamination is dealt with on a voluntary basis via the planning regime and compulsory remediation under the CLR is used only when necessary. As a result, planning will remain the main route to clean-up in the UK since it is normally associated with an unlocking of often significant value. The reuse of brownfield land is (rightly) strongly supported in planning and environmental policy. More fundamentally, it is driven by the perversions of our post feudal land ownership structure that ensure that only a fraction of greenfield sites will ever become available. This is despite the desperate national need for more developable space for people, homes and business to be available at a more reasonable base price. This has obviously waned somewhat as new developments have slowed to a trickle in the recent downturn (outside of east London). It is left to over 300 under- resourced local authorities to survey the entirety of the UK land base and they, or the Environment Agency, to judge on a case-by-case basis, whether the legal definition of "contamination" in the CLR has been met, and if so, to embark on a cumbersome, contentious and often protracted negotiation with owners, former owners etc. This practice has led to an inadequate use of the CLR.

Whilst no recent statistics have been released, we know that by 2007 "[a] total of 781 sites had been determined as contaminated land under Part 2A in England (659) and Wales (122) by the end of March 2007. Of these, 35 were designated Special Sites being enforced by the EA.

CLR BASICS

Part 2A of the legal regime is supplemented by legally binding Guidance. "Contaminated Land" is defined in Section 78A(2) EPA 1990 as land: "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." 'Significant' in terms of significant harm and significant possibility of significant harm is not defined in the Act although the Guidance broadly defines and explains the basis on which this may be ascertained by the local authority. This process is well described in the case studies that follow.

The CLR, after ten years of remaining largely unchanged, underwent a period of consultation culminating in the issuance of new Guidance in April 2012. In the Government's Impact Assessment on the simplification and shortening of the Guidance, it was concluded that the CLR remained fit for purpose but the Guidance had major flaws that "undermined the effectiveness of the regime and created considerable regulatory uncertainty". In particular, the Guidance failed to adequately explain how a local authority should decide whether land is contaminated. Other areas of concern were that the determination that a site is low risk took too long; that higher-risk sites were not targeted sufficiently; and that some local authorities set the standard for remediation too high, resulting in the under-use of brownfield sites. The contaminated land regime was therefore causing results that were inconsistent with the Government policy to "ensure brownfield land is developed first […] reducing the need for development of greenfield land."

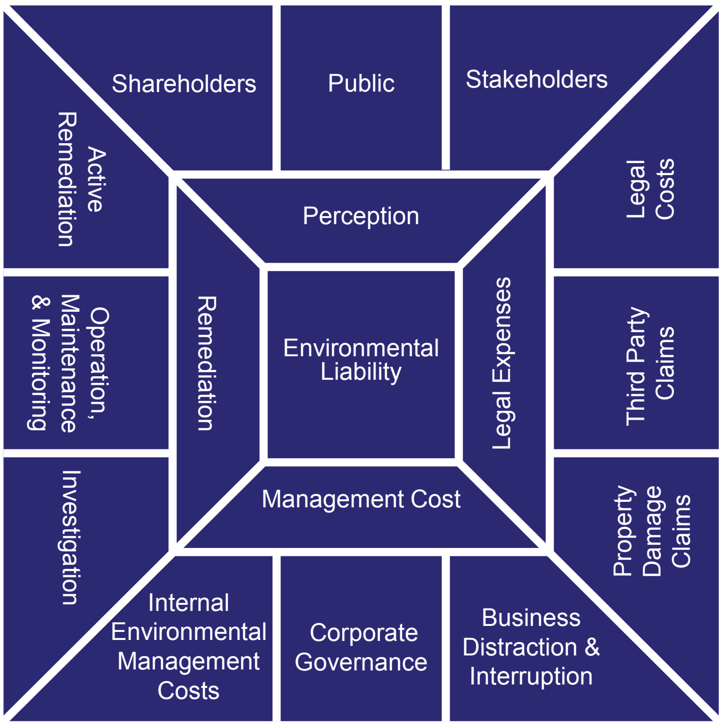
The new guidance goes some way to remedy these issues. It clarifies for example that where normal levels of contaminants are found in soil this "should not be considered to cause land to qualify as contaminated land" and that land should be considered no further under the Part 2A regime. This clarification should reduce the unnecessary time spent by local authorities investigating small amounts of contamination and should also "reduce potential blight on land with only normal levels of contamination" .

The Guidance sets out a four-category framework for deciding whether land is contaminated, where Category 1 land is the most contaminated and Category 4 land is uncontaminated. This new framework is "intended to provide a legal basis for creating technical guidance". An expert panel will be set up to assist councils in making decisions between Category 2 and 3 land in the most difficult cases. Case studies will be published as an additional aid.

Some additional significant changes to the CLR are the introduction, at long last, of a higher threshold test for pollution of controlled waters (from s.86 of the Water Act 2003) and the clarification of the definition of the legal trigger for "significant harm being caused to human health". The health effects of contaminated land, usually the most emotive trigger to clean-up are dealt with further in this Issue by Sarah Bull [**Page 12**].

Initial reactions to the Guidance have been tentative. The Chartered Institute for Environmental Health expressed disappointment that the Guidance "still does not give us the key advice on the line between contaminated land and non-contaminated land." Industry participants also argue that one of the main reasons that the contaminated land regime is not as effective as it could be, is that "enforcing authorities cannot afford to clean up at a faster rate", a barrier of particular concern as budgets of regulators are being cut. As such, they argue that the changes to the contaminated land regime may fall short of creating a significant impact. The Guidance has also clarified the "hardship test" for recovery of costs for remediation so that where a local authority is not able to recover all costs of remediation from one person, it may still recover part of the costs, thereby alleviating a portion of the financial burden on local authorities. DEFRA is in the process of producing various technical guidance to supplement the new regime. The overall effects of these changes are yet to be seen.

Figure 1: The different facets of environmental liability



TRANSACTIONAL MANAGEMENT OF ENVIRONMENTAL LIABILITIES

Liability for remediation of contaminated land will be imposed, in the first instance, on the person(s) who knowingly permitted the contaminating substances to be present in, on or under the land (referred to as 'Class A' persons). If no Class A person can be found, that liability will pass to the current owners or occupiers of the site (whether or not they knew of the contamination). Buyers ought therefore to take a cautious approach when purchasing land, especially once other legal triggers in other regimes are properly considered.

In fact, sensible and responsible clients adopt a systematic approach to environmental due diligence (EDD) whether in the sale, purchase or financing of a business, company or land. Responsible buyers need to know about the associated risks that could arise. On the sell-side, a sensibly scoped vendor EDD programme can smooth the transaction considerably. Lenders who could end up with direct or indirect liability need to have an idea of the true net value of the asset.

Adopting the head in the sand option is rarely optimal unless one is systematically avoiding becoming a "permitter" with requisite "knowledge" and thus falling into the Class A category as a knowing permitter. Such a strategy is risky and may be a breach of EHS and company law or certain fiduciary duties.

It can be critical not only to identify and quantify these risks as part of the EDD process but also structure the deal so that suitable and practicable measures are implemented to ensure that risks end up where the parties intend (including with 3rd party risk takers). This is the essence of systematic risk management and it is essential to plan ahead and assemble the team with the right skills, as the answers will normally require detailed technical, legal and sometimes insurance input.

It may comfort readers to know that solicitors can also be liable for inadequately dealing with contamination in their transactional dealings. The Law Society issued a "Contaminated Land Warning Card" to solicitors in June 2001, recommending that all solicitors in transactions involving land should consider the CLR and advise their clients of the potential liabilities. Solicitors can stumble into hot water if they fail to do so especially if unidentified liabilities arise subsequently.

There are several ways in which we manage environmental risks in transactions. Some of the "Menu of Risk Transfer Solutions" are shown in **Figure 1** and include: price adjustments, site carve outs, pie crust leases, contractual warranties and indemnities, agreements on liabilities (and other CLR specific terms reflecting the CLR exclusions and apportionment of liability rules– sold with information, payment made for remediation

▲ **Figure 2: Managing Risk Transfer Solutions**

etc) through to proactive voluntary remediation and the use of insurance and other 3rd party risk transfer options (the attribution of environmental liabilities to contractors on some basis constitute the most frequently used risk management tools).

It is possible to arrange specific environmental insurance to cover risks relating to historic contamination and ongoing operational risks or to stand behind an indemnity with only a weak covenant. Environmental insurance is a useful tool to transfer risk to a third party where neither the buyer nor seller is willing to accept the risk. Credible policies can be negotiated and premium prices have plummeted as a dozen or more insurers are now hungry for the premium.

CONCLUSION

Notwithstanding the recent changes to the CLR, in light of the range of legal triggers and liabilities for contamination, companies should consider investing in early action to manage contaminated land risks since a 'stitch-in-time' approach can often apply and make limited early action rational and cost-effective. ES

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Assessing background concentrations of priority substances

Andrew Hursthouse summarises the challenges inherent in measuring the natural versus the anthropogenic chemical composition of the soil.

The measurement of background concentrations of chemical elements or substances presents a challenge for environmental scientists. Although it would be useful to have a set of baseline measurements against which contamination could be measured, we need to consider that planet Earth is a very heterogeneous system both physically and chemically, and the chemical variation in particular is enormous.

Statements on the natural chemical composition of the Earth's crust are updated regularly[1], and provide estimates of the abundance of rock-forming elements such as aluminium, silicon, magnesium and iron which are orders of magnitude more abundant than the rarest elements (the rare earth elements and precious metals). However, the degree of human influence on the operation of the environmental system is such that it has been considered to have initiated a new geological epoch – the Anthropocene[2]. This reflects the rapid rise in industrial activity and swollen population levels, increasing the influence on natural surface processes, such as sediment production in river basins, water and air quality, and the amount and distribution of biomass. In addition, industrial development has seen the extraction and exploitation of a number of strategic elements, some highly abundant (e.g. iron, aluminium and manganese) others that are much rarer (e.g. tin, tungsten and lead). New, synthetic substances have also been introduced, the majority of which are organic chemicals that are designed for specific actions (such as additives and pest control) or are by-products from industrial activity, waste disposal and biodegradation. All of these activities can cause significant contamination of industrial or urban landscapes.

So how do we make reasonable assumptions about the likely levels of potentially toxic elements and compounds, particularly for specific environments where humans are exposed? How do we make judgments about whether what we measure is reasonable or unexpected? These are ultimately impossible questions, but ones that we must try to answer, particularly in framing decisions in a regulatory environment based on risks to human health.

This article presents a brief review of where and how information on background levels might be generated or identified, to assist in the management of land contamination. It does not offer definitive solutions or datasets, but illustrates some of the contributing information sources and issues that might be considered when looking to establish likely background or reference levels. It also focuses predominantly on UK data sources, but is relevant to the wider international situation[3].

MEASURING AND GENERATING DATA

Within urban or disturbed landscapes, the normal rules of soil formation may or may not hold. Soil is inherently heterogeneous and layered, and highly spatially variable in environments that have had human disturbance, often for many centuries and with variable degrees of industrialisation. In typical soil maps, survey data is missing for urban or disturbed regions, and they contain little or no information about ground materials. These may be typical soil material or a mixture of technological artefacts – concrete, brick, steel and wastes such as ash and clinker, all of which are chemically distinct and physically variable.

The variability of urban soils, and the diversity of survey approaches and analytical methods requires a firm understanding of any methods used to generate data. This should recognise the uncertainty associated with sampling through the analysis protocol to the interpretation or manipulation of data. Generating background values or using secondary information in the derivation of assessment values must include a range of factors, whether considering naturally abundant substances, such as potentially toxic elements (cadmium, arsenic, lead, copper and chromium) or anthropogenic substances (persistent organic pollutants such as pesticides, combustion products, pharmaceuticals and petroleum products). The following are important points to bear in mind:

- Sample location: It is important to identify places where samples can be collected to reflect the accumulated inputs from normal activities, such as diffuse emissions from commercial and domestic heating, transport and energy production, without the direct inputs from contaminating activities. Sites should be chosen with similar soil characteristics to those likely to be encountered on any affected sites. Multiple locations may be selected and aggregated to reflect natural variability and provide confidence in defining a range of concentration levels that provide appropriate background information.
- Extraction for analysis or direct reading: In other words, determining how samples should be processed to generate values. Extraction using strong acids (for metals) and solvents (for organics) are common, but for many elements these methods represent partial extraction. This is acceptable so long as any comparison data sets have been derived using similar approaches. The use of more gentle extraction schemes introduces further uncertainty as the application of these schemes or using a single extractant generates data that is sensitive to the operational characteristics of the test, i.e. the concentration of reagents in relation to buffering by the nature of the solid phase. Most

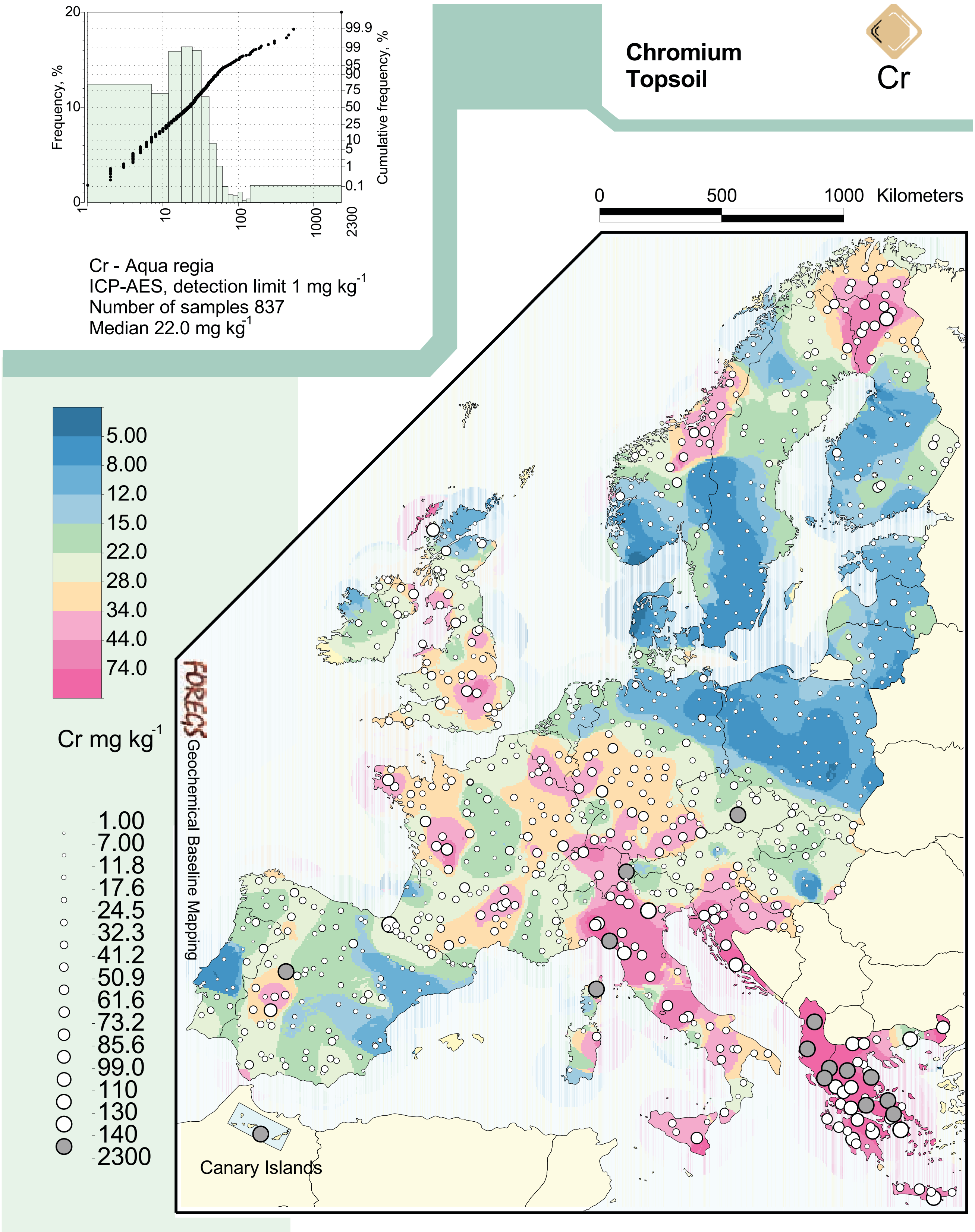
schemes developed for soils are appropriate in land-contamination assessment, but where large amounts of anthropogenic matrix occur, sample-to-sample variation can be influenced more significantly by the matrix than the contaminant. Increasingly, for metal analysis, field-based detection is used, often hand-held X-ray fluorescence instruments. Whilst robust and with proven precision, the instrument has a fixed sampling volume, concentrated on surface materials. The precision and accuracy of the approach can be improved with relatively simple field protocols involving minimal sample preparation:[4]

Photo credit: Andrew Husthouse

- Sample treatment and handling: This relates to the need to assess (if possible) the physical and chemical properties of the contaminants being evaluated, and their stability in light of details of sample collection and handling. Questions of stability relate to volatility and degradation, primarily for organic substances and volatile elements such as mercury.

- Detection limits and quality assurance and control: For baseline definition, this aspect can prove quite problematic. Baseline concentrations for many substances are likely to be low, and defining analytical protocols that are sensitive enough to capture and report positive values is difficult. There are therefore requirements that analytical accuracy and precision can be demonstrated. This can be notoriously difficult and is commonly shown through the use of appropriate reference materials. These materials, with certified analyte contents, should reflect the material sampled and the method of analysis used, and whilst many hundreds of materials are available worldwide, the diversity of soil materials and contaminant concentrations proves a challenge to the confident determination of background concentrations. Even with rigorous quality control, inter-laboratory comparison, even for routine determinations, can be difficult to control[5].

- Comparison of data to look for enrichment: Methods for providing an evaluation of the significance of concentration levels can apply typical environmental geochemical approaches, originally developed as mineral survey strategies, to emphasise their significance. Natural soil-formation processes include enrichment, as many elements (and compounds) can be enriched by the presence of typical soil components such as clay minerals and naturally occurring organic matter. Soil content in a target area can be compared to a similar matrix from outside the study area, statistically evaluated to check the significance of measured concentrations from the background, including those methods used in geochemical prospecting. A variety of normalisation methods and pollution indices are frequently cited in reports, some of which were developed from sediment contamination studies, whilst others are from regional geological averages. The balance depends very much on the availability and reliability of other data and the (financial) ability of the assessment to generate its own dataset, bearing in mind that reliability increases with the number of samples analysed.



▲ **Figure 1: Coverage and data of the showing Chromium concentrations in European topsoil as provided by the the EuroGeosurveys Group**

SURVEY INFORMATION AND COMPLEXITY

A number of regional approaches can be identified to specify the range of soil variability for soil metals in particular. These are frequently part of the national geochemical or soil baseline surveys. Many countries have established such organisations to provide an assessment of economically viable mineral resources as part of understanding geological baselines or to assess the agricultural capacity of soils. The approach to establishing chemical properties is defined by the objectives of the survey and should be recognised when using data. The use of stream sediments to characterise regional surface chemistry has been used to identify localised enrichments often associated with the exposure of potential ore deposits and the historical legacy of their exploitation. The work of the British Geological Survey (BGS) through their Geochemical baselines and Medical geology themes[6] provide an excellent resource for the UK[7], and links to wider international activities of, for example, the EuroGeosurveys group[8]. An example of the coverage and data is shown in **Figure 1.**

BGS datasets for stream sediments and waters that have been enhanced with topsoil information are available for many UK regions and a number of major urban centres. These studies concentrate on elements but have been extended to include a limited number of organic pollutants, i.e. polycyclic aromatic hydrocarbons (PAHs) and polychlorinated biphenyls (PCBs)[7].

Other National Soil Survey resources are available predominantly for agricultural soils, including potentially toxic elements, some pesticides and mildly extractable fractions. Datasets are available for England and Wales[9]; for Scotland a National Soils Archive[10] is being re-sampled to look at changes over 25 years; and more recent publication of data for Ireland[11] highlights the use of spatial geostatistics in survey outputs.

The advantage of these studies is their wide spatial coverage and the fact that samples have been analysed in a consistent manner. This means that regional signatures are reliable and therefore useful for comparisons in

Table 1: Summary of potentially toxic element content (mg/kg, dry) and pH variability in top soils (0-10cm) of a park area from the centre of six European cities

City		pH	Hg	Cr	Ni	Pb	Zn	Cu
			(mg kg-1)					
AVEIRO Portugal N = 26	Max	7.7	0.13	15	28	38	82	61
	Min	5.0	0.032	6.0	6.0	7.0	18	8.0
GLASGOW UK (a) N = 13	Max	5.7	5.2	34	53	676	377	113
	Min	4.5	0.31	24	21	98	102	24
GLASGOW UK (b) N = 14	Max	5.5	0.69	131	53	414	305	113
	Min	3.9	0.26	21	18	114	67	33
LJUBLJANA Slovenia N = 25	Max	7.2	0.86	33	43	225	300	78
	Min	6.0	0.15	13	15	39	84	21
SEVILLA Spain N = 32	Max	7.2	1.3	51	37	247	191	72
	Min	6.4	0.11	21	21	43	73	30
TORINO Italy N = 25	Max	7.3	0.90	288	315	257	317	123
	Min	4.9	0.21	150	154	68	116	44
UPPSALA Sweden N = 25	Max	7.6	1.2	56	34	116	193	90
	Min	5.8	0.015	12	7.0	7.0	27	8.0

target areas. The main limitation might be the low sample density compared to the size of the site being considered.

CONTRIBUTIONS FROM DISCRETE RESEARCH STUDIES

A large number of studies, some commissioned by government departments[12] and undertaken independently by research groups in academic and other institutions, have contributed to a massive and increasing repository of information: for example, an internet search for urban soil pollution produced over 32,000 hits on the Web of Knowledge database on 27 June 2012. This repository can be of benefit in providing a source of data to enable an understanding of particular pollutants or contamination scenarios. The extent of this work is too wide to review here, but examples that may highlight potential contributions and the diversity of information are available. The studies are often short term and restricted to particular locations, which might compromise comparisons. Care must also be taken to recognise that methods for data generation can be highly variable beyond the points raised above relating to the chemical diversity of sample matrices.

Nevertheless, work has been done to address a number of uncertainties. The variability of contaminants in urban soils has been comprehensively considered in, for example, pan-European studies, demonstrating order-of-magnitude variation in surface-soil mercury content over 25-m distances in parks and open spaces[13]. The relationship between urban inputs and natural backgrounds for the potentially toxic elements (PTE) PAH and PCB in rural-to-urban transects[14,15]; and variation between and across cities[16,17,18,19] have been studied. Temporal changes have been assessed through innovative use of land use change records to highlight locations where soils have remained undisturbed or subject to particular uses in restricted time periods[20]. Doing so has allowed researchers to assess the impact of rapid economic development on soil quality across urban regions, which can enhance site-specific understanding. To support these approaches, techniques to identify the contributions from different sources of elements and anthropogenic compounds have been developed. Associations of elements reflecting urban activity can be assessed to have differing degrees of influence on soil types using multivariate statistical analysis[17] or characteristic ratios of organic compounds such as PAHs to discern different fossil-fuel sources[19].

CONCLUSIONS

We can clearly see from the variety of data sources that there is a wide variation in methods of data production, handling and interpretation. The broad trends in contamination levels are relatively clear, but high levels of uncertainty as well as variability even in undisturbed soils are difficulties for risk assessors and decision-makers in defining background concentrations. Discrete exercises focused on particular sites or locations will always provide more robust definitions. However, the vast wealth of information published in the open literature does have value in providing clues as to the typical or expected values, but these should not be used in isolation but instead 'in conversation' with the land-contamination community – professional practitioners, regulators and the academic science base. ES

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If the poison is in the dose, how much is too much?

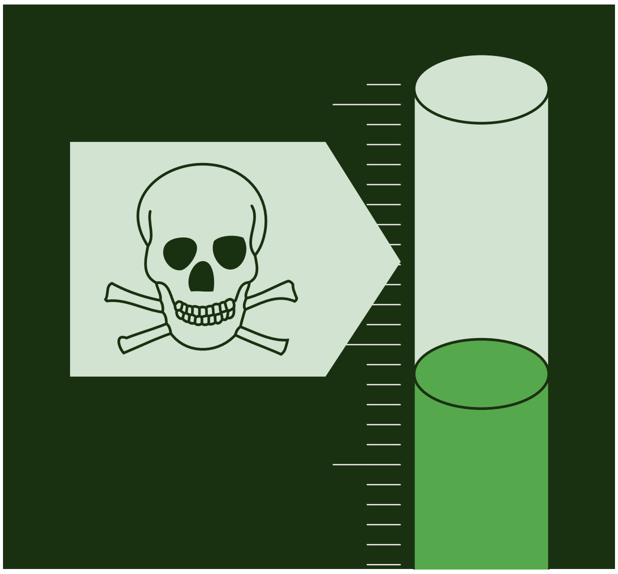
Paul Nathanail assesses proposed changes in the Government's Dose Response Roadmaps

Regulatory science is the interface of science and regulation; of knowledge creation and societal response to knowledge. Sometimes scientific findings drive the need for regulation. Sometimes societal concerns expressed through policy as regulations identify unknowns that science can explore. The United Kingdom's long standing policy on contaminated land management is an excellent example where regulatory priorities have both been driven by and driven science.

Polluted land is an unwanted legacy – an externality in economic terms – from past industrial and waste management practices. Land and water have been polluted by concentrated and processed minerals and by man made substances such as solvents and fuels. The consequences where such pollution is substantial were highlighted by Rachel Carson's Silent Spring and even Dr Seuss' The Lorax. More recently Hollywood has portrayed the human cost of pollution in A Civil Action and Erin Brokovich.

Since 1994, UK policy has been to prevent new pollution and to restore damage caused by historic pollution through the planning system and as a last resort through regulatory intervention principally under the Environmental Protection Act 1990 (EPA 1990). Part 2A of the EPA 1990 introduced a duty on local authorities to identify land posing unacceptable levels of risk, including land posing a 'significant possibility of significant harm' (SPOSH). A fundamental of the science of poisons – toxicology – is that the poison is in the dose. Toxicologists study how organisms respond to different doses and seek to then calculate doses that are protective of human health. However doses that confidently represent such tolerable or minimal levels of risk are of necessity very conservative. They do not represent doses that would pose a significant possibility of significant harm with all the consequences that regulatory intervention brings. From both a scientific and policy perspective government has resisted pressure from consultancies and local authorities to publish a numerical level of risk which if exceeded indicates SPOSH. While some toxicologists have pointed out that the question of what dose represents SPOSH is not a scientific one but rather one where social, economic and ethical issues should determine whether land represents SPOSH or not, the decision is not always so intractable.

Since the inception of Part 2A in 2000 in England and Scotland (2001 in Wales; Northern Ireland's equivalent has yet to come into effect) some 1000 sites have been determined by local authorities as contaminated land under Part 2A and over half on the basis of SPOSH. The remediation of most of the sites posing SPOSH has been paid for either by Local Authorities or through the Contaminated Land Grant and its precursors by Central



Government. However it has become apparent to many and specifically Defra that many of these determinations were based on exceedences of the safe doses described above rather than on scientifically defensible doses indicating SPOSH and therefore justifying regulatory intervention.

Into this regulatory vacuum, a group of scientists have developed a simple tool to assist local authorities decide if a given site is posing SPOSH on the basis of the best available toxicological data. However the hotly contested debate on 'how much is too much' meant that sound science alone was not enough. Widespread acceptance of that science was also essential for the tool to improve decision making by local authorities.

Traditional approaches to the interpretation of toxicological studies involved identifying a key study; choosing a point of departure (PoD) in the dose-response data within that study and then deriving a health criterion value by applying safety factors to that PoD. The more recent benchmark dose level (BMDL) approaches have used statistical curve fitting techniques to define the PoD. Either way much information is ignored. Specifically high doses where unwanted adverse effects are observed are not taken into account and regulators are left with a limo-bar low level of dose against which to compare exposure levels from a specific site. The problem is that the regulatory regime embedded in Part 2A, but not within the planning system, requires intervention where a high-jump high bar is exceeded – the data on high doses must be considered when deciding how much is too much.

The solution was to preserve, normalise and standardise the entire dataset of dose-responses and compare estimates of contaminant exposure from individual sites against that dataset in what have now become known as the LQM/CIEH Dose Response Roadmaps.

For each substance, the dose response data standardised to units of mg of contaminant per kg bodyweight per day and with the effects normalised on a US EPA 10-point scale are plotted. In addition the familiar health criteria values and PoD values on which they are based are plotted. On top of that graph, the doses estimated from each of the soil samples analysed at a particular site are plotted. The vast majority of analyses fall well outside doses which cause adverse affects – the high bar has not been cleared. A small number of analyses fall well within dose levels where significant harm can be expected if no regulatory intervention occurs – the high bar is obviously cleared and intervention is warranted. It is expected that a very small number of analyses will not be resolved using the Dose Response Roadmaps.

The proof of concept of the Roadmaps was developed by an open workshop with some 40 participants from the private and public sectors held in the University of Nottingham's David Ebdon Computer laboratory. Prototypes were then developed by the small team of scientists responsible for most of the generic assessment criteria currently in use in the UK. The final version of the Roadmaps were then made available first to workshop delegates and subsequently the rest of the contaminated land practitioner community. Users of the Roadmaps are trained by those who developed them and their employer's annual licence of the Roadmaps allows them access to both roadmaps for new substances and to ask questions of the developers.

At the time of writing, the LQM/CIEH Dose Response Roadmaps have been successfully used in sites in Wales, Scotland and England, including under the new Part 2A Statutory Guidance introduced in England in April 2012. By being simple to understand and use, although admittedly difficult to develop, they make the risk evaluation stage of risk assessment much simpler in the vast majority of sites being considered by Local Authorities under Part 2A.

The recently announced Defra project (reference SP1010) to revise the basis for generic soil screening levels may well result in changes to the health criteria values and less conservative risk evaluations under the planning regime. But the project will neither replace nor undermine the validity of the LQM/CIEH Dose Response Roadmaps to decisions under Part 2A. ES

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Contaminated land – Is there a risk to health?

Sarah Bull examines the research evidence and concludes that there are no clear answers.

England and Wales has a vast legacy of land contamination, involving a wide range of substances, due either to underlying geology or to industrial pollution. In most cases, areas that are considered to pose an unacceptable risk to health are mainly industrial and waste disposal sites resulting from mining, chemical manufacture and landfills. It has been estimated that there may be approximately 300,000 ha of land in England and Wales that are potentially contaminated following such activities.

There are many examples of areas that have been affected. Shipham in Somerset is contaminated with heavy metals such as cadmium, lead and zinc, due to the substrata being rich in mineral deposits leading to mining activities[1]. Areas of Newcastle-upon-Tyne have been contaminated with dioxins and furans that have potentially been linked to historic industrial land use dating back to the 1890s[2]. Extensive soil contamination by chromium slag originally from a chromium-processing factory was discovered in Rutherglen and Cambuslang in the south-east of Glasgow[3]. Sandstone quarries in Weston (in Cheshire) used for the disposal of industrial waste were shown to cause the presence of volatile compounds such as hexachlorobutadiene (HCBD). Areas of Cornwall and west Devon were used for mining ores of tin, copper, arsenic and other minerals, and such historic industries left extensive areas of spoil heaps with elevated levels of arsenic. Added to which, natural mineralisation and dispersal of ore materials has resulted in widespread contamination of arsenic across the region[4]. The list goes on. But does such soil contamination really pose an unacceptable risk to health?

Various studies have been carried out to assess the potential impacts of contaminated land on human health. The earliest study, carried out by the Royal Commission on Environmental Protection[5] in 1996, stated that "it was not aware of any study that provided firm evidence of adverse effects of contaminated land on health". A similar view was presented by a subsequent study carried out by Kibble and Saunders[6], although they noted a stronger link between landfill sites and congenital abnormalities and low birth weights based on a study carried out by the Small Area Health Statistics Unit (SAHSU)[7]. The most recent research was carried out by the Food and Environmental Research Agency (Fera) on behalf of Department of Environment, Food and Rural Affairs (Defra). Fera concluded that overall there is no evidence for widespread impacts of contaminated land on human health but equally, the potential for health impacts has not been dismissed[8].

ACUTE OR REVERSIBLE HEALTH EFFECTS

In terms of acute or reversible health effects, most studies carried out relate to landfills. These show a link between exposure and self-reported symptoms such as headaches, dizziness, rashes, irritation, and nausea[9,10,11]. Such symptoms were particularly evident near sites that had odour issues. However, there are also residential sites with exceedingly high levels of chemicals such as lead or hexavalent chromium[12] but residents exposed to such levels have few reported acute health effects, if any (pers' comm').

PSYCHOLOGICAL EFFECTS

Several studies have noted the presence of psychological effects such as stress and anxiety in residents living near hazardous waste sites[13], although it is largely unclear whether such effects have an underlying toxicological mechanism. From working with residents whose houses are undergoing soil investigations, many have said they are stressed, anxious and depressed due to being

concerned about the potential long-term health effects and the financial implications of having their home labelled as contaminated.

HYPERTENSION

Cadmium and lead are well known to cause cardiovascular effects such as hypertension. However, no increases in blood pressure were reported in populations living in cadmium-contaminated areas in Germany[14], Belgium[15,16] or the UK (Shipham)[17]. In contrast, blood cadmium levels were shown to be higher in hypertensive subjects in Korea compared to normotensive comparators, although the source of cadmium was not discussed, so no definite link to contaminated land could be made[18]. Studies also failed to show a correlation between lead in soil and hypertension[19].

KIDNEY EFFECTS

The nephrotoxic property of cadmium is also well known, hence the plethora of studies looking at renal biomarkers, although it is important to note that the presence of biomarkers does not necessarily mean the presence of kidney disease. Studies based on a population in Belgium showed a significant association between biomarkers of renal dysfunction and cadmium in soil[16,20]. More recently, low levels of cadmium in urine and renal biomarkers were of borderline significance in a population living near the Avonmouth zinc smelter in the UK[21]. Conversely, several studies have reported individuals being exposed to high concentrations of cadmium in soil without an increase in body burden or adverse health effects in Germany[22], the UK[7,17,23,] France[24], Jamaica[25] and Korea[26]. Kidney effects have also been investigated after exposure to other chemicals. Exposure to HCBD resulted in some renal effects that improved when exposure ceased, and it was therefore suggested that non-carcinogenic risks were minimal[27].

BONE DISEASE

Several studies have also indicated a relationship between cadmium exposure and bone dysfunctions, even at very low levels of environmental exposure[28,29,] although in many studies reporting positive effects, exposure is via the diet. By contrast, other studies have failed to show a link[26].

CANCER

In general, most chemical-induced cancers have a long latency period, and it is therefore difficult to demonstrate a causative link between cancer and exposure to chemicals in soil. Nevertheless, many epidemiological studies have been carried out to look at the prevalence of cancer in contaminated areas or around landfills. Several studies have proposed a link between cancer and living near landfills containing hazardous waste[30,31], although many other studies failed to demonstrate such a link[32,33,34,35,36]. In terms of specific chemicals, exposure to asbestos[37,38], dioxins[39] and arsenic [41,42] from land was thought to increase the incidence of cancer in some populations. Conflicting results have been presented for cadmium[1,43,44,45] and TNT[46,47]. In this study noincreasein cancer incidence was reported for populations exposed to hexavalent chromium in Glasgow[3].

BIRTH DEFECTS

Studies looking at reproductive outcomes are usually easier to carry out than cancer studies as a long latency period between exposure and onset of disease does not. The results presented in the scientific literature have been conflicting, possibly due to the lack of statistical power small studies. There is the case of the incidence of birth abnormalities in Corby being significantly greater than the average, and in 2009 a judge ruled that the disposal of contaminated waste may have caused the birth defects. However, no other individual single-site studies have demonstrated a causative link with congenital anomalies, including a study in Glasgow[48], although several studies did show a significant link with low birth weight and/or preterm delivery[49,50]. In contrast, several multiple-site studies have demonstrated a plausible link between living near landfills and congenital anomalies[51,52,53,54] as well as low birth weight[7,49,50].

The outcome of all these epidemiology studies is more important than ever following the recent revision of the Statutory Guidance to Part 2A of the Environmental protection Act 1990 in which the new four-category test is specified.

Category 1 describes land that is clearly contaminated, for example because similar land is known to have caused significant harm in the past. But, as mentioned in the Impact Assessment that accompanied the revised Statutory Guidance, Defra and the Welsh Assembly Government have recently stated that, to their knowledge, no site in England or Wales has been determined as contaminated due to it causing actual significant adverse health effects[55].

Category 4 describes land that is clearly not contaminated and the new Category 4 screening levels will aim to describe the level of risk that is precautionary but which avoids the excessive caution of the current generic assessment criteria. Evidence from epidemiological studies and literature reviews such as that from Fera will provide an additional layer of evidence when deriving and using such screening levels in the risk assessment of contaminated land, as they show that exposure to contaminants in soil have yet to be linked with adverse health effects.

To summarise, many epidemiology studies have been carried out to investigate a potential causal link between exposure to chemicals in soil and adverse health effects. From the available literature it appears that there is limited or inadequate evidence of a causal link, with the potential exception of some reproductive and psychological effects, although the latter may not be chemically induced. This lack of effects may be due to the long latency period of some diseases and the difficulty in correlating it to events that have occurred many years previously, or simply due to the lack of statistical power of smaller studies. It may however be due to some other unknown cause. I cannot help feeling that if people are not showing acute symptoms after living with very high levels of lead in their gardens, then there is an underlying issue that we have yet to fully understand. **ES**

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CASE STUDY

Contaminated land and health: Issues of Life and Death

Alex Stewart outlines the role of public health practitioners at the interface between health issues and the public.

Public health departments are often asked for advice on contaminated land issues by local authority contaminated land officers, environmental consultants, members of the public and other health professionals. The questions can relate to any of three angles: the contamination itself (Will it cause harm?), possible exposure to contaminants (What is the risk from breathing, eating, touching them?) or increased awareness of disease (Is this health problem related?). All angles have within them legitimate questions (spoken or silent) about what public health departments can do to save lives and protect health.

RISK ASSESSMENT

The classical approach to contamination has been to identify and characterise the hazard (a landfill or old industrial site, for example, in which the concentration of the contaminant such as lead or naphthalene, is then investigated), then undertake an estimation of the level of exposure of the local community to the identified contaminants, consider whether it is possible to measure local health effects, and finally produce a quantitative or qualitative risk assessment that is communicated as widely or narrowly as is appropriate.

However, this presumes that we have positive answers to questions such as:

- Do practitioners talk the same language as the public, who often have a poor understanding of contamination and exposure mechanisms?
- Do practitioners understand what the public worries about? Authorities' and consultants' responses may not meet the public's expectation.
- Do practitioners really weigh measurable hazards and control measures against the troubles that the community may encounter? How?
- Do practitioners know how to take into account any bigger picture (e.g. people's priorities)?
- Do practitioners have the tools or potential for communicating risk more clearly?

ART AND SCIENCE

Public health is defined as "the art and science of preventing disease, promoting health, and prolonging life through the organized efforts of society"[1]. The relevant science is fairly easy to identify in contaminated land issues, but crosses the divide between hard science and social science, and includes environmental sciences and geochemistry, risk estimation, toxicology, epidemiology, sociology and psychology. However, the application of the science may test practitioners severely. For example, there are over 31 million recognised chemicals, of which 640,000 can be bought commercially, with 70,000 routinely transported within the UK, and 500 new chemicals introduced into the market each year. Despite these large numbers, only about 5,000 chemicals have reliable medical toxicology information for acute or chronic exposure, and there is even less information on the toxic effects of mixtures.

Source	Resulting pollution
Artisanal gold mining	Mercury
Industrial estates	Lead
Agricultural production	Pesticide
Lead smelting	Lead
Tannery operations	Chromium
Mining and ore processing	Mercury
Mining and ore processing	Lead
Acid battery recycling	Lead
Arsenic in groundwater	Arsenic
Pesticide manufacturing and storage	Pesticide

Table 1. Top ten toxic pollution sources globally[7].

Measuring disease relevant to contaminated land is hard, since most diseases are caused by several factors acting at once (e.g. length of exposure, vulnerability, age, sex) and many mild diseases are not seen by health professionals and therefore not counted. Furthermore, the geographical distribution of deaths from a disease is not necessarily the same as that of ill-health caused by the disease (see Figure 1). Only a few people die of any disease, more are seen in the NHS, yet more have symptoms at home, even more could have an unseen change within them that reflects an exposure but not any disease process, while the total of those that are exposed will exceed even that (see **Figure 2**).

Risk calculations seldom take account of the stress, worry, strained relationships, community conflict, division and stigmatisation resulting from the declaration, or merely the investigation, of land as contaminated[2,3]. This is where the art of public health comes in.

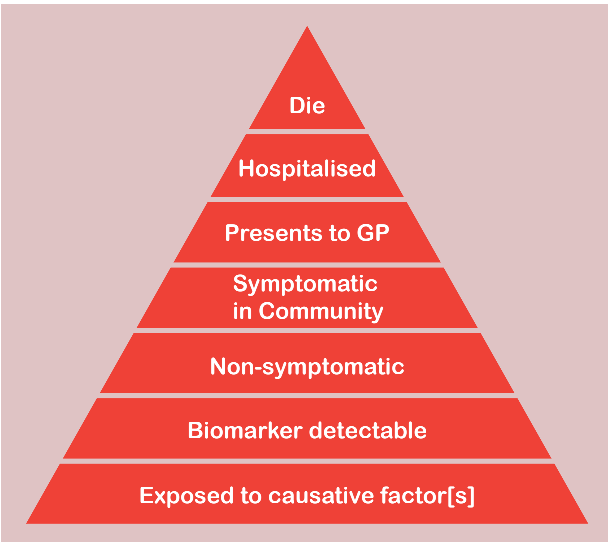
The art of public health can be described as "imaginative communication". It complements the science, allowing improved understanding, response and communication around issues that, while relevant, are not easily quantified in contamination situations, nor are they easily translatable from one situation to another. These include issues such as the community, its historical context, and the differing agendas and expectations of participants[4] (see Figure 3). None of these can easily be standardised.

Imaginative communication allows a non-rational (which is not the same as irrational) response to worry and anxiety, which do not respond to numbers or reason. To answer stress and fear a level of trust must be developed, while bringing a vision for tomorrow and giving a sense of security. It is important for practitioners to care for the community affected by contaminated land issues, even when their response appears to be excessive.

DEFINING HARM

UK contaminated land regulations are based on an understanding of the known or anticipated toxicological consequences of known exposures to chemicals. Such toxicological and health analyses result in an estimate of the probability of adverse health consequences (how likely it is to happen given certain circumstances), which is not the same as an estimate of SPOSH and POSH: Significant Possibility of Significant Harm (previous regulations), Possibility of Significant Harm (new regulations), which are both concerned with whether adverse health consequences might happen in a specific, but hypothesised situation.

The regulations are written to be applied within a legal framework; health works in a different framework and the artistry is in bringing them together in a meaningful and useful manner, so that the users and owners of the land, and the regulators are all protected from, or respond appropriately to, various adverse outcomes, whether health-related, legal, commercial or economic.



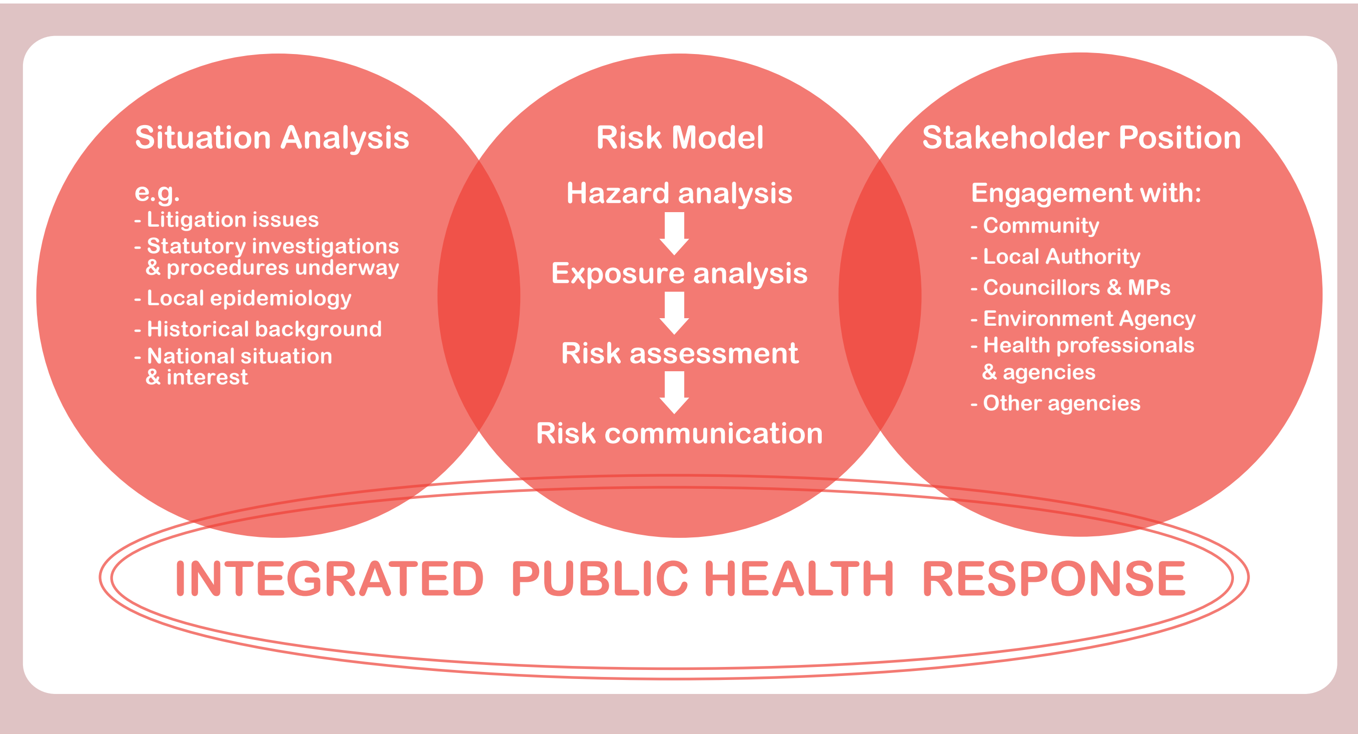
▲ **Figure 2: Disease pyramid showing the decreasing numbers from those exposed to those who die**

REDUCING HARM

This difference in approaches can add to the stress already felt in a local community around a contaminated site as they juggle the advice or views of different professionals whose approaches sometimes do not appear to interact with each other. This is a further reason for engaging communities in the overall response.

A lay community faced with a contaminated land issue in Cheshire were successfully engaged in discussions that subsequently directed investigations, analyses and remediation[5]. The deaths of two young children and the discovery of an old, unregistered landfill under their homes left the community feeling extremely vulnerable. The ongoing engagement with them by the relevant professionals (health, local authority, environmental consultants) over the extended time of the necessary investigations gave the community ownership of the situation and considerably reduced their anxiety and stress. No link was found between the landfill and the children's deaths. However, the community was satisfied that the investigation 'had left no stone unturned' and the resulting essential remediation had been completed.

Anxiety and stress are well recognised causes of ill health and may be, in the developed world, the main determinant of any contamination-related health effects in a community living on or near a site being investigated under the contaminated land regulations[3]. There are very few developed-world examples that have shown clear links between contaminated land and adverse health effects. Love Canal (in the USA) is probably the prime example, and even there, there has been serious dispute, although it should be clear to the reader of Herdman's report[6] that pregnancy outcomes were adversely affected. In the developing world the situation is probably the reverse, at least at the moment, with physical ill-health being more noticed than mental health issues. Of the top ten toxic pollution problems on a global scale, most have some component of land contamination[7] (see Table 1). Within these top ten problems, all the pollutants are well recognised; in other words, partial understanding and solutions already exist. As often, the questions are not so much about what should be done, but how it should be done and by whom.



▲ **Figure 3: A fully integrated public health response incorporates the context and people involved as well as a standard risk assessment[4]**

KEY CONSIDERATIONS FOR COMMUNITY ENGAGEMENT

In engaging with the local community and other interested parties, there are several questions that are worth asking:

When and how should the data be released to community? Should the data be released raw or interpreted? While professionals may feel the latter is the only way, the community may wish to see the uninterpreted data and may be able, with support, to help analyse and interpret it, particularly once an understanding is gained of the relationship between accepted national or international standards and the concentrations of contaminants observed locally.

How is the media to be managed? In one example, a community successfully selected one journalist, leaving the rest of the press unhappy but simplifying life for everyone, including the investigation team.

How are expectations best managed? There needs to be a mixture of personal contacts, letters, leaflets and more formal meetings where full discussion of all items of interest can take place without fear or favour. All this will be eased by giving the community access to the expert professional team through one accepted person who is trusted by all.

To whom will the reports be assigned: the community or the professional agencies? An example of good practice would be to write the final report for the community, and only distribute it to the agencies once community-led revisions are complete.

How will remediation proposals be formulated? Who decides? Does all remediation need to be the same? Differential remediation can be undertaken in a situation where the community is involved in the whole process of investigation and review. The very involvement in the development of the investigation can enable the community to perceive the need to remediate different parts of a site in different ways.

What should be done with health data? Who sees it? Of all the data in any investigation, personal health data needs the most sensitivity and privacy.

What else is needed? Perhaps the key to community involvement is, as noted above, compassion. In Cheshire and Merseyside families have been rehoused, not from any worries about heightened risk to health, but on compassionate grounds because of stress.

Health issues around contaminated land can be complex and need a thoughtful multi-agency approach with an eye to the local context and the needs of interested parties in order to achieve both a realistic risk assessment and a satisfactory outcome for everyone. ES

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Bioaccessibility of potentially harmful soil elements

Mark Cave outlines in-vitro methods that are reducing the costs of assessing the human health risks of soils.

Quantitative guidelines for assessing risks from potentially harmful elements in soil are associated with several scientific problems. There are difficulties in establishing concentrations of contaminants beyond which risks from exposure to these contaminants would be unacceptable. This requires not only scientific (toxicological) information on the health effects, but also an element of judgement on what is unacceptable risk. In addition, soil is only one of the sources of contaminant exposure, and its effect, and the cost of dealing with it, needs to be kept in proportion with the total exposure to contaminants from all sources.

Whether contaminated soils pose a human health risk depends on the potential of the contaminant to leave the soil and enter the human bloodstream. In terms of human health risk assessment there are three main exposure pathways for a given contaminant present in soil. The largest area of concern is the oral/ingestion pathway, followed by the dermal and respiratory exposure routes[1].

There is, therefore, a clear need for a practical methodology that measures the fraction of the contaminant in the soil that, through oral ingestion, can enter the systemic circulation of the human body and cause toxic effects. This is known as the oral bioavailability and can be formally defined as the fraction of an administered dose that reaches the central (blood) compartment from the gastrointestinal tract[1]. This is distinct from the oral bioaccessibility of a substance, which is defined as the fraction that is soluble in the gastrointestinal environment and is available for absorption[1].

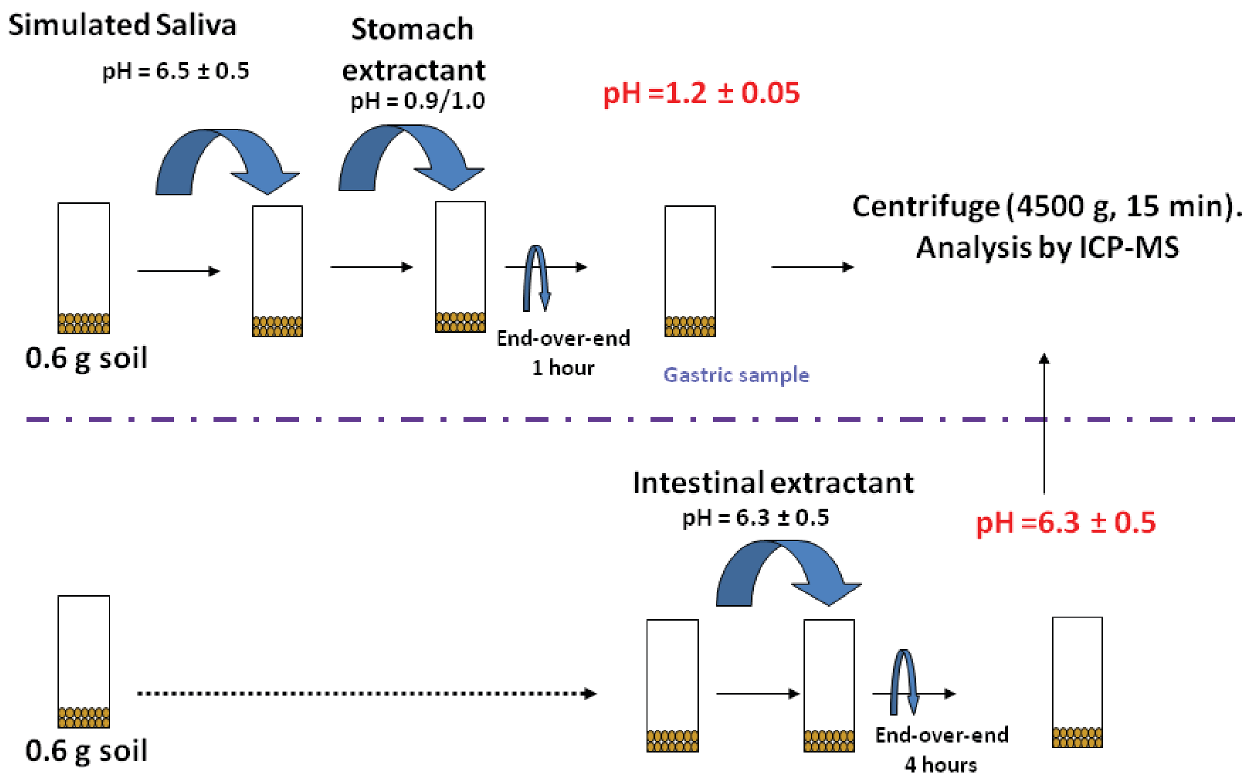
The use of total contaminant concentrations in soils provides a conservative approach as it assumes that all of the metal present in the soil can enter the bloodstream. Results from animal tests[2] suggest that contaminants in a soil matrix maybe absorbed to a lesser extent and show fewer toxic effects compared to the same concentration of soluble salts of the contaminants in a food or liquid matrix. In many cases there is no distinction made between the intake for contaminants that are bound to soil and those which occur as a vapour or are released during processes like digestion into solution (the bioaccessible fraction). For example, children may ingest arsenic-contaminated soil by eating soil or putting dirty hands or soiled toys in their mouths. Empirical studies have sought to demonstrate a relationship between the type of contaminated soil and the fraction of arsenic that can be dissolved by digestion[3]. Using such studies may improve our knowledge of the intake of bioaccessible organic and inorganic compounds in the future, as this parameter represents a better estimate of exposure than total concentration of soil contaminants.

IN-VIVO AND IN-VITRO METHODS

Since bioavailability data is essentially related to the amount of contaminant in the animal/human bloodstream, the data must be produced from the dosing of animals with contaminated soil and the subsequent measurement of the contaminant in the blood or organs of the animal; these are known as in-vivo animal models. Bioaccessibility data, however, is normally determined in a test-tube environment (in vitro) and represents the amount of contaminant dissolved in the gastrointestinal tract prior to crossing the mucosal walls. The amount of pollutant that is actually absorbed by an organism is generally less than or equal to the amount that is mobilised[1]. In-vivo dosing trials have used a variety of animal species such as rats and rabbits, but species that have similar gastrointestinal tract characteristics to human children, such as immature swine, are preferred and have been shown to be reasonable analogues for children[4]. In this type of testing, known amounts of contaminant are added to the feed of the species being tested, in the form of soluble salts or contaminated materials. Bioaccessibility extraction tests are generally based around the gastrointestinal parameters of young children of up to three years of age, since they are thought to be most at risk from accidental ingestion of soil. Also, since children can absorb a higher percentage of contaminant through the digestive system than adults, they are more susceptible to adverse health effects[5].

Mammal dosing trials are time-consuming and expensive. To supersede the use of animals in determining the bioavailability of potentially harmful elements for human health risk assessment, or to estimate bioavailability where animal studies are not available, a potential alternative is the use of in-vitro tests.

In-vitro testing regimes are used as predictors, as they do not provide absolute bioavailability data, since this can only be done at present by in-vivo techniques. As the cost and time required to perform in-vitro techniques is small in comparison to in-vivo methods, a larger number of soils can be assessed to fully characterise a site. A number of in-vitro bioaccessibility tests for mimicking human ingestion have been reported in the literature and have been comprehensively reviewed[6,7]. Of these, there are four batch extraction methods that are most commonly used: the physiologically based extraction test (PBET) originally developed by Ruby *et al.* (1996)[3]; the in-vitro gastrointestinal method (IVG)[8]; the Dutch National Institute for Public Health and the Environment method (RIVM)[6,9,7] which is mainly used in Europe; and the relative bioaccessibility leaching procedure (RBALP) which was developed specifically for lead in soils[10]. The PBET, IVG, and RIVM methods use extraction media that closely mimic the chemical environment of the human gastrointestinal system, i.e. they are physiologically based, whereas the RBALP uses the physiologically relevant pH of the stomach but uses a glycine buffer as the extraction medium. As a result of research carried out by the Bioaccessibility Research Group of Europe (BARGE) and other research groups, it was clear that the different bioaccessibility tests showed similar trends when used on the same soil samples, but the different operating conditions for each test produced wide-ranging bioaccessibility values between the methods[11]. To overcome this problem, BARGE took a joint decision to progress the development of a harmonised in-vitro bioaccessibility method (the unified BARGE method – UBM)[12] as seen in **Figure 1**.



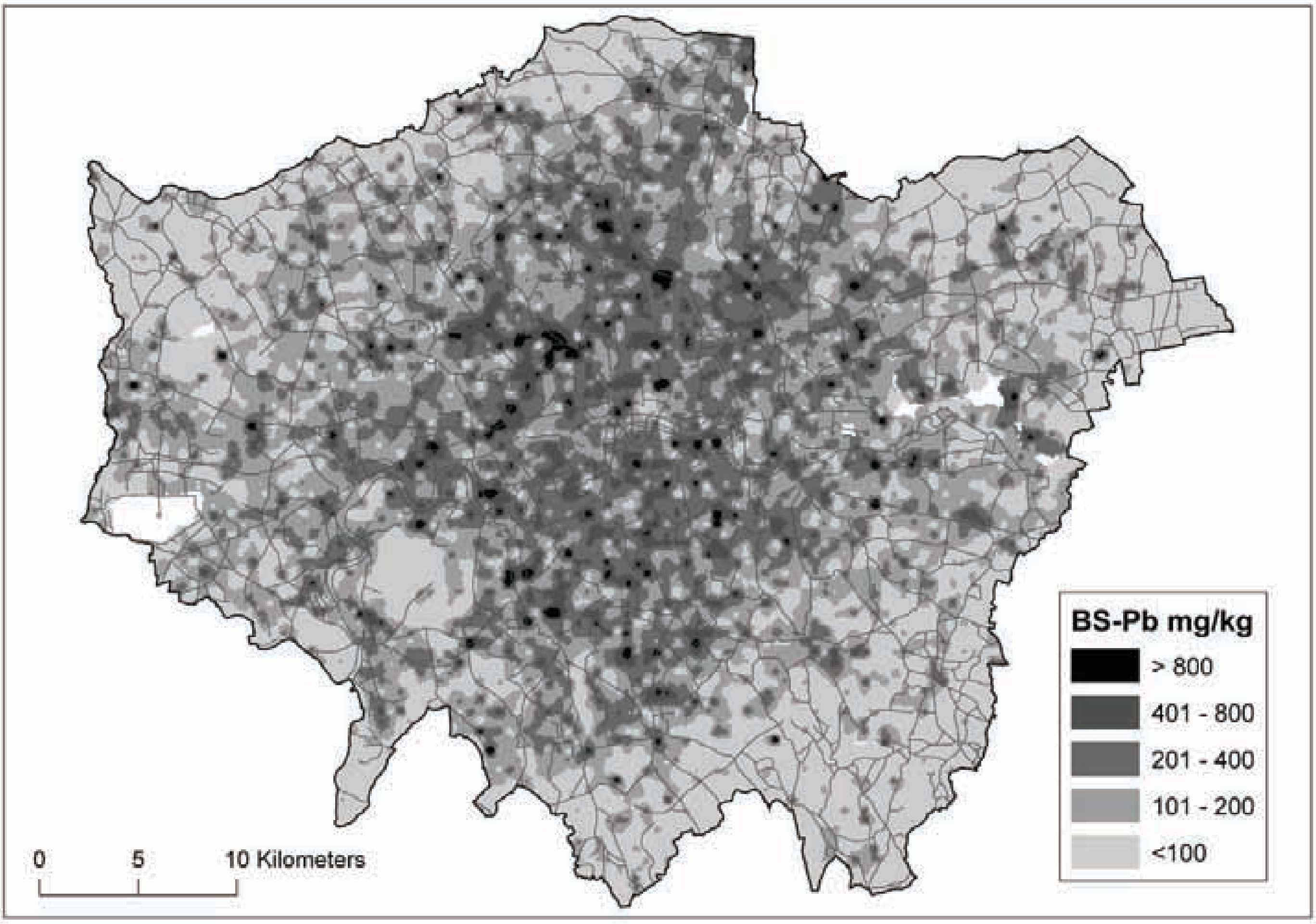
▲ **Figure 1. Schematic outline of the BARGE unified method**

The main criteria for the test were:

- it should be physiologically based, mimicking the human physico-chemical environment in the stomach and small intestine. This should help to obtain good agreement with in-vivo data and enhance public understanding of the test;
- it should represent a conservative case;
- there should be one set of conditions for all potentially harmful elements (PHE) being studied;
- it must be demonstrated that the test is a good analogue of in-vivo conditions; and
- the test must be able to produce repeatable and reproducible results within and between testing laboratories.

The chosen method was the RIVM method[9] as this was considered to be the most suitable static or batch method available, and therefore more likely to be adopted by testing laboratories. The RIVM methodology has also gained acceptance by regulators in both the Netherlands and Denmark. Modifications were made to the RIVM methodology to ensure adequate conservatism and that the in-vitro test was robust and applicable to the different soil types found in a range of different countries. A schematic outline of the method is shown in **Figure 1**.

The UBM has now undergone initial inter-laboratory trials[13] and been validated against an in-vivo model[2]. It has become widely accepted as the method of choice in European countries.



▲ **Figure 2: Estimated bioaccessible lead in topsoils in the Greater London area; solid lines indicate roads (Source: Ordnance Survey Strategic data © Crown copyright 2012)[16]**

WIDER IMPACTS OF MEASURING BIOACCESSIBILITY

In a study of the financial impact of research carried out for the NERC (Natural Environment Research Council) by BGS (the British Geological Survey)[14], examples of the use of bioaccessibility testing were given that showed that:

- in one case the assessment enabled the re-use of existing site materials as part of the land-remediation process, which subsequently led to reduced costs of approximately £3.75 million. In addition, approximately 3,750 lorry trips to landfill were avoided and 105 tonnes of carbon-dioxide equivalent were saved; and
- in another example, BGS worked with Land Quality Management and University of Nottingham staff to save between £7 million and £30 million in remediation expenses on one site. The more accurate bioaccessibility testing not only reassured local residents, but also allowed the stalled housing market in the area to restart.

Across England, there are an estimated 15,470 ha of land in need of remediation. The cost of remediating this land is between £100,000 and £325,000 per ha, giving a potential market of £1.5 billion to £5.0 billion.

The research methods developed by BGS have the potential to save between £3.9 million and £12.6 million per year in remediating derelict land for development. Over a 20-year period, these cost savings are estimated to have a Net Present Value of between £55 million and £179 million.

The method is also being used on a national scale to provide bioaccessibility maps for arsenic and lead[15,16]. **Figure 2** shows an example of how a combination of the UBM test and data modelling has produced a map of the bioaccessible lead in soils in the Greater London area.

Bioaccessibility testing cuts across a number of disciplines including chemistry, geochemistry, toxicology, human health and risk assessment, and recent collaborative work untaken by research consortia such as the BARGE group have enabled the development of standardised testing protocols that have had a direct impact on human health risk assessment and demonstrable economic benefits when used on a national and international scale. ES

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Olympic Park From old fridges to Olympians: The remediation of the London 2012 site

Transforming 246 ha of heavily contaminated land is no mean feat. **Mike McNicholas** and **Emma Fenton** describe the remediation of the Olympic site.

The remediation of the Olympic site was overseen by Atkins, the official design services provider for the London 2012 Olympic and Paralympic Games. The work included demolishing existing buildings, excavating and cleansing the land, and revitalising the rivers, canals and natural habitats across the Olympic Park.

THE OLYMPIC PARK: FACTS AND FIGURES

In 2006, the Olympic Park was home to a mountain of old fridges, a landfill site, railway sidings, concrete plants, bus garages and abanwdoned industrial sites including a chemical works, plastic and glue factories, an oil refinery and a tar distillery.

It took just two years to prepare the site for construction. Historically, it would have taken between five and 15 years to carry out a project of this size.

During the clearance of the site 140 archaeological trenches were dug, uncovering artefacts including a 19th-century boat, skeletons from the Iron Age and a hut from the Bronze Age.

98 per cent of the materials from demolitions on the Olympic site were re-used or recycled. This required removing some of the structures brick by brick.

Over 2 million m^3 of soil were excavated, of which around 80 per cent was re–used.

Over 200,000 m^3 of contaminated ground water were treated – enough to fill 80 Olympic-size swimming pools.

THE OLYMPIC PARK: REMEDIATION AND EARTHWORKS

During site investigations, 3,500 exploratory holes were dug to analyse the geological composition of the earth.

The site became home to a soil hospital, which treated 700,000 m3 of soil – enough to fill two billion drinks cans.

Contaminated soil was treated using a variety of techniques including soil washing, bioremediation, chemical stabilisation and geotechnical stabilisation.

A new technique was used for the first time in the UK to decontaminate groundwater around the Olympic Stadium. Naturally occurring bacteria were dropped down boreholes to degrade ammonia in the water.

The site was cleared of invasive species including around 4 ha of Japanese knotweed – the equivalent of 10 football pitches.

THE OLYMPIC PARK: ECOLOGY AND WILDLIFE

The four-year wetlands and river edge engineering project covered 8 km of riverbanks, 2.6 km of soft bioengineered banks including reed beds, wetlands and wet woodlands, 2 ha of ponds, 20 ha of grassland, 9,000 m^2 of rare native woodland, 45 ha of new habitat and 310,000 native plants comprising 28 species.

A 12–month planting trial determined which species were best adapted to the site's tough conditions and the best way to plant the vegetation. It was concluded that the most appropriate way to plant the 310,000 seedlings onsite was to establish them on coir mats before transporting the 18,000 m^2 of matting for planting in 2010.

Three new ponds were created in the North Park. Two were designed to dry up in the summer to provide different types of habitat; the third will retain water, enabling endemic British aquatic wildlife to flourish.

675 bird and bat boxes were placed around the park.

Around 4,000 smooth newts, 100 toads and 330 common lizards were relocated during the site clearance.

Habitats have been created for house sparrows, swifts, starlings, black redstarts and bats as well as invertebrates.

Other species that are being encouraged to colonise the site include bats, otters, water voles, European eels, common lizards, frogs, toads, grey herons, kingfishers, reed warblers and sand martins.

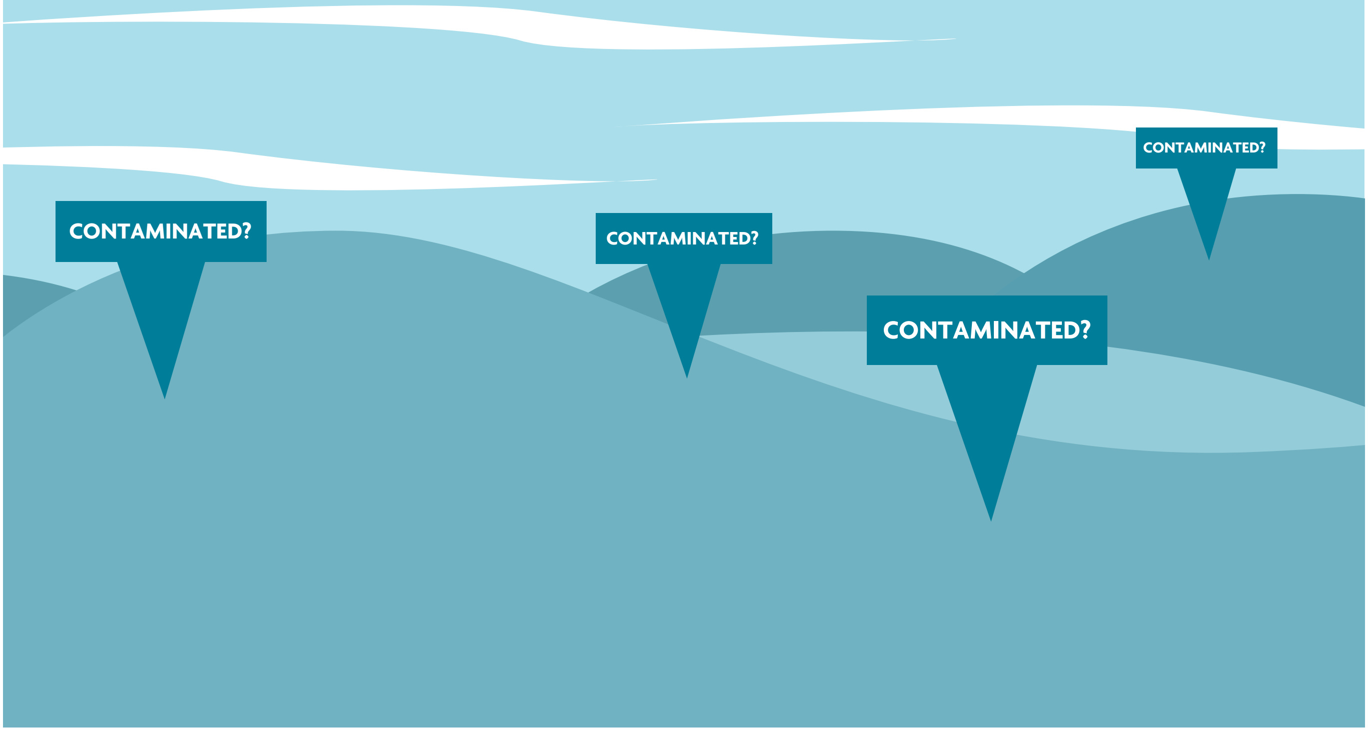
The black redstart, of which there are only 100 breeding pairs in the UK, has been sighted on the Olympic Park since the transformation – a key achievement in rebuilding habitat.

Photos from Atkins Global image database

It is widely believed that London won the right to host the 2012 Olympics because of its commitment to use the event to create a lasting legacy. The organisers boast that 75 per cent of all the money spent on the event goes on something that will remain long after the Games are over. Crucial to that is the creation of one of Europe's largest urban parks around the sports venues. After the Games, the site will be transformed from a secure compound into open, inviting parkland and will be called the Queen Elizabeth Olympic Park. ES

Mike McNicholas is Atkins' London 2012 project director and managing director of Atkins' Design and Engineering division in the UK.

Emma Fenton is Project Officer at the Institution of Environmental Sciences.



Uncertainty in contaminated land characterisation: Inevitable but Manageable

Michael Ramsey explains the difficulties in characterising different contaminated land types.

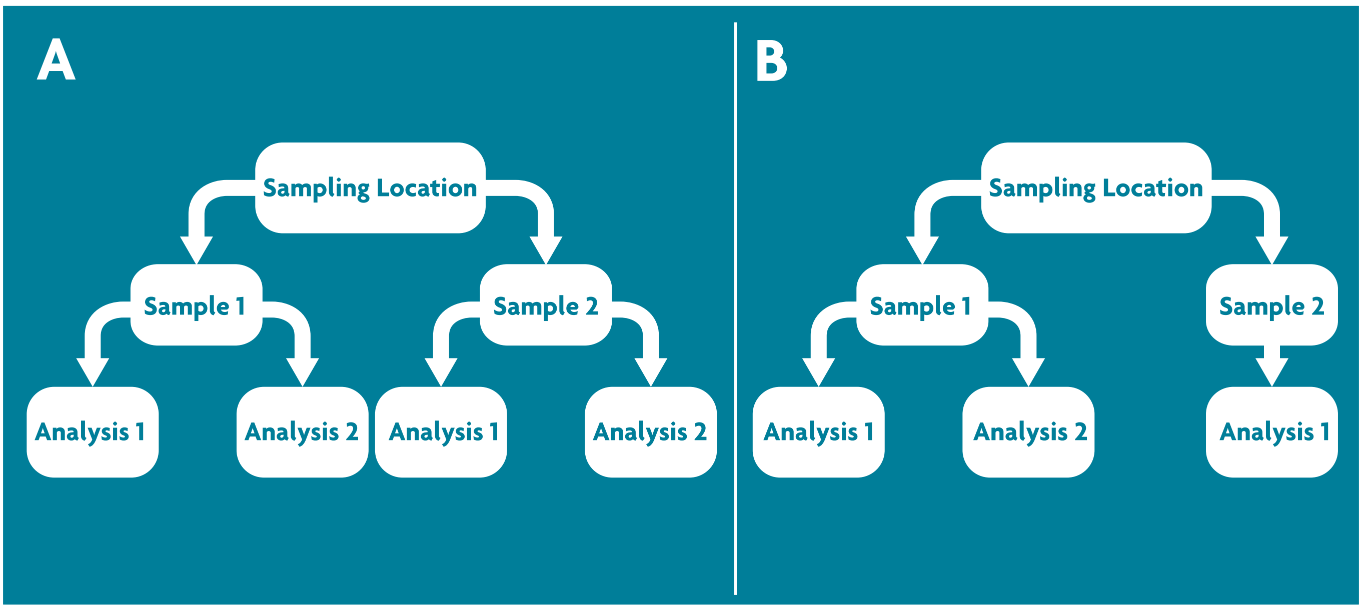
Contaminated land is a classic example of a widespread environmental issue. Pollution is often distributed spatially in a very heterogeneous way, which is problematic for scientists studying the effects of the contamination and for regulators trying to limit the impacts of the pollution on the health of humans and the environment in general. The problem becomes evident when investigators take samples of the soil in order to measure the concentration of the contaminant. If just one sample is taken at each of a large number of locations across a site, and a lab takes just one measurement from each, then it appears that a clear picture (a conceptual site model) of the level of contamination hazard is unambiguous. If however, a second set of samples is taken at the same locations and analysed, the measured concentration is often very different. This means that the measurement of concentration at that location has a high level of uncertainty (e.g. 30–80 per cent). This illustrates the small-scale heterogeneity at each location. To use an analogy, when sampling a bowl of muesli with a spoon to find out the concentration of brazil nuts, duplicated spoonfuls will usually have very different numbers of nuts.

There are two possible approaches to this problem. The first approach, now generally used, is to take only one sample from each location and assume that they are each a representative sample of that location. The uncertainty in the measurement is then either ignored entirely or assumed to arise only from the analytical procedure used in the laboratory to determine the concentration of the contaminant (e.g. <10 per cent). The second approach is to evaluate the uncertainty in each measurement result that arises from the sampling procedure as well as from the analytical procedure. A practical way to achieve this, agreed at the European level, is to use the duplicate method, which is now described in the new British Standard on contaminated land assessment . Once this total uncertainty of each measured concentration value is known, the hazard can be interpreted with a specified degree of confidence (e.g. 95 per cent), and a probabilistic interpretation can be made of the level of contamination across the site.

ESTIMATING WHOLE-SITE UNCERTAINTY

It is not feasible to evaluate the uncertainty at every single sampling location. Instead it is evaluated for the whole site by inv estigating around 10 per cent, but no less than eight per cent, of all the locations, selected at random across the site. At each of these selected locations, a duplicate sample is taken in a similar way to the original, but using a fresh interpretation of the sampling protocol. For example, the position of the sampling location might be determined with a hand-held GPS, but that might mean that it is equally likely that the location could be found up to 2 m away in any direction. In that case, a duplicate sample should therefore reflect this ambiguity and be taken 2 m from the original, in a randomly selected direction. The heterogeneity of the contaminant concentration in the soil at this 2 m scale therefore contributes uncertainty to the concentration of the contaminant at that nominal location, as studied with that sampling protocol. An average value of the measurement uncertainty is estimated from these typically eight duplicated measurements, which can then be applied to all of the individual measurements taken at that site. The standard uncertainty of measurements u is expressed in the same units as the concentration value (e.g. mg/kg), and is often estimated as the standard deviation of an individual measurement. It is well known that the standard uncertainty increases with the concentration value. To overcome this limitation, it is better to express the uncertainty relative to the mean concentration value as a percentage. To give the 95 per cent confidence interval, this is multiplied by two, to give the expanded relative uncertainty (U). The value of U is effectively constant as the concentration increases, assuming the contaminant concentration is well above (i.e. > ten times) its analytical detection limit. Applying a single value of U to all the individual measurements at a site means that the calculated value of u is unique to each location. If there is prior reason to believe that the site has two different former land uses that would be expected to give rise to different levels of heterogeneity, it is preferable to estimate different values of U for both sub-sites.

▼ **Figure 1: Experimental designs, (a) balanced and (b) unbalanced, for estimating uncertainty of measurement arising from both sampling and chemical analysis, to be applied at 10 per cent of locations across a site**



USING STATISTICAL TECHNIQUES

This measurement uncertainty has a contribution from the procedure of chemical determination of the contaminant concentration. This contribution can be evaluated at the same time by taking two analytical test portions from the sample duplicates, in what is called a balanced design **Figure 1a**. All of the random components of the uncertainty can be evaluated from the set of 32 replicated measurements (eight locations with two samples and two analyses on both) using a statistical technique called classical analysis of variance (ANOVA). The assumes that the frequency distributions are normal (i.e. Gaussian), but if they have less than 10 per cent of outlying values from an otherwise normal distribution, then a good estimate of the statistics of the underlying normal distribution can be given by a newer technique called Robust ANOVA. By definition, the uncertainty should also contain components from the systematic errors, such as sampling and analytical bias, and well as the random ones discussed above. Where the heterogeneity is large, as is often the case for contaminated land, then the systematic effects from sampling can be assumed to be negligible, but the contribution from the bias of the chemical analysis can also be incorporated into the estimate of the uncertainty. This procedure was originally developed for measurements made on samples taken to remote laboratories, but has been shown to be equally effective for measurements made in on-site labs or using new in-situ measurement tools such as portable X-ray fluorescence (XRF, see **Figure 2**) . There is inevitably a marginal increase in the cost of a site investigation when the measurement uncertainty is evaluated. However, this increased cost can be reduced by 33 per cent by using an unbalanced design in which an analytical duplicate is required for only one of the sample duplicates (**Figure 1b**) prior to robust ANOVA .

Once the value of the uncertainty is known for each location, as well as the value of the concentration, then a much more rigorous interpretation of the contamination is possible. This is because the contamination hazard can be mapped out in a probabilistic way, allowing for the uncertainty in deciding when concentrations exceed

'Uncertainty in measurement of contaminant concentration has traditionally been ignored, or at best severely underestimated.'

Figure 2: Using X-Ray Fluorescence to treat soil

a specified threshold value. The uncertainty values can also be propagated in all of the normal calculations made to concentration values. For example, in human health risk assessment the uncertainty in estimates of hazard can be used to evaluate uncertainty in estimates of both exposure and of risk . Another issue that can be addressed is whether the measurement (and therefore the sampling) is fit for purpose (FFP), or whether the levels of measurement uncertainty are too high, or even too low. The first approach to judging FFP, for mapping geochemical variation between locations, suggested that the measurement uncertainty should contribute less than 20 per cent to the total variance of a geochemical investigation . The second approach included financial considerations, not just of the cost of the sampling and analysis, but also of the costs that might arise from misclassification of the contamination. The latter approach has been applied to many routine site investigations and has shown that designing the site investigation to give an optimal level of uncertainty can reduce the total cost of site development by up to £200,000.

In conclusion, uncertainty in measurement of contaminant concentration has traditionally been ignored, or at best severely underestimated as that arising only from the chemical analysis but not the sampling. The new techniques that have been described here, such as the duplicate method[2], can be used to make much more realistic estimates of the full measurement uncertainty. Once that uncertainty is known, a much more robust interpretation of the state of the contamination and its potential consequences for human health become possible. Recent guidance on the assessment of contaminated land from Defra , requires investigators to explicitly report and minimise all sources of uncertainty. It is therefore clear that the importance of uncertainty, in all aspects of hazard and risk assessment, has become recognised by the regulators. In a broader context, uncertainty is present in all environmental measurements of contamination, not just for soils, but also for waters, sediments, wastes, gases, and biota including food and feed. The evaluation of this uncertainty, often using the duplicate method, has been reported for measurements in many of these different media[1,9]. In all of the parts of the environment, a recognition of uncertainty in measurements, as well as in the models of geochemical processes, such as those for climate change, is essential for the highest quality of scientific research, as well as for more robust regulatory control. ES

Michael H. Ramsey FRSC CChem has been Professor of Environmental Science at University of Sussex for over 10 years. He worked for 3 years in the Mining Industry in Zambia, and then for 20 years in research and lecturing posts at Imperial College London.

IES: New members and re-grades

Members	Occupation
Angela Goodhand	Air Quality Consultant
Judith Chan	Environmental Scientist
Laura Dreiling	Environmental Consultant
Brendan Mclean	Scientific Officer
Angela Duerden-Hertrampf	Environment Specialist
Kit Choi	Environmental Manager
Kwok Tam	Senior Environmental Engineer
Alison Crooks	Planning And Permitting Manager
Ka Leung	Inspector of Works
Shannon Thompson	Environmental Scientist
Tolulope Ajayi	Senior Environmental Affairs Advisor
Richard Kulczak	Senior Associate Director
David Schofield	Senior Consultant
Jonathan Matcham	Environmental Consultant
Rachel Dunk	Academic Director
Abdul Memon	Senior Associate Professor

Associates	Occupation
Florence Kirk-Lloyd	Assistant Consultant
Malcolm Hughes	Environmental Protection Officer
Kirstie Atkins	Compliance and Technical Assistant
Gareth Hughes	Environmental Scientist
Victoria Simkin	Optical Consultant
Jennifer Christian	Assistant Sustainability Consultant
David Copeland	Graduate
Jessica Hambling	Environmental Support Officer

Fellow is for esteemed individuals in the feilds of environmental science and sustainability who are held in high regard by their peers

Member is for those individuals who have substantial academic and work experience within the field of environmental science.

Associate is for individuals beginning their environmental career or those working on the periphery of environmental science.

Affiliate is for individuals with an interest in environmental issues but don't work in the field.

Remediating Helpston

Eric Cooper describes the work being done to clean up a herbicide-contaminated aquifer.

Situated to the north-west of Peterborough, the villages of Helpston, Marholm and Ailsworth are set in a quintessentially English landscape. Whilst the sleepy rural character of the area appears to have remained largely unchanged for some 200 years, an unseen major pollution incident has slowly taken its toll on groundwater beneath the surface.

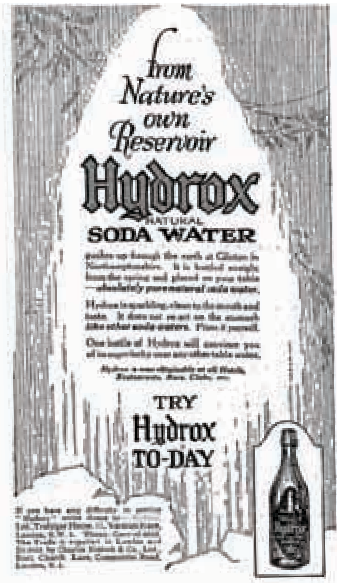
The Jurassic Lower Lincolnshire Limestone is an underground aquifer that is widely used for public water supplies. Locally it used to be a source of mineral water: for some 30 years prior to 1952, groundwater from springs near Marholm was abstracted and bottled with the brand name Hydrox. It was claimed at the time that the water was "excellent table-water for general use, and especially for persons who suffer from gouty and rheumatic tendencies and for persons who suffer from hyper-acidity and indigestion."

ENTER THE DRAGON

So it is a terrible pity that in the 1980s, quarry operators deposited some 40 tonnes of pesticide waste in two landfills near Helpston. Since then, an unseen seepage from the landfills has contaminated a large area of the aquifer with the herbicide mecoprop. Hydrox founder, Herbert 'Toffee' Neverson, must be turning in his grave at the careless despoiling of his famous spring waters.

In the late 1980s the former National Rivers Authority was alerted by Anglian Water that mecoprop was being found in the public water supply (PWS) abstraction boreholes at Etton (**Figure 1**). It was quickly established that the source was two former landfills, known as Ailsworth Road and Ben Johnsons Pit, located close to the village of Helpston, some 3 km from the PWS abstraction site. Investigations and remedial works to deal with the problem began immediately. After 1995, the job became the responsibility of the Environment Agency (EA). Hydrock (no relation to Hydrox) was appointed in 2008 to continue the programme of remediation works at the site on behalf of the EA.

Where major aquifers such as the Lincolnshire Limestone are present, groundwater is extremely important to England's public water supplies. Anglian Water, which serves the Peterborough area, is 50 per cent reliant on groundwater for the provision of drinking water. Given that the maximum acceptable concentration of mecoprop in drinking water is 0.1 µg/l (one part in 10 billion), the impact of 40 tonnes of pesticide soon becomes obvious.



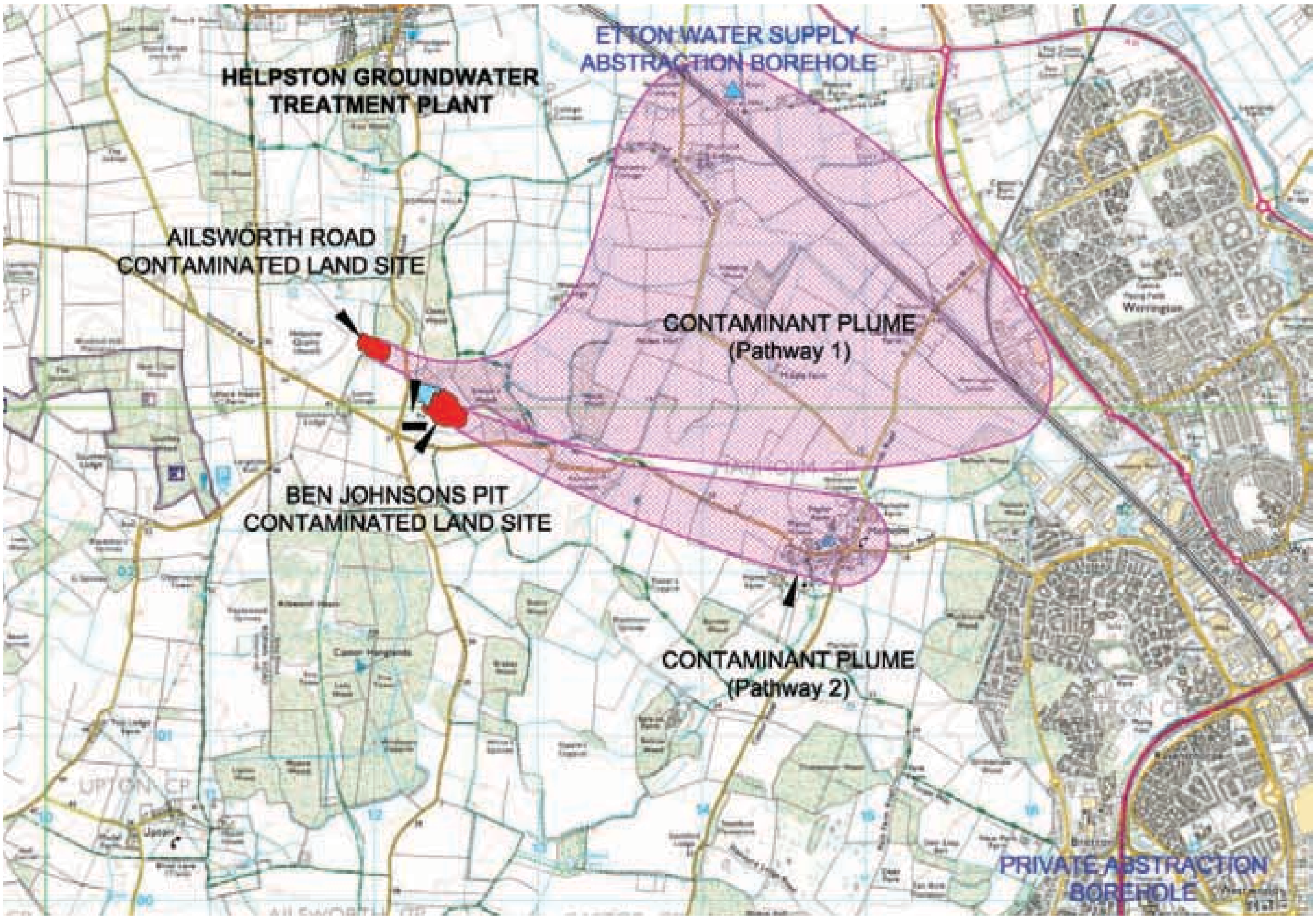
▲ **Hydrox mineral water, produced in Helpston in the first half of the 20th century**

PAYING FOR OUR PAST

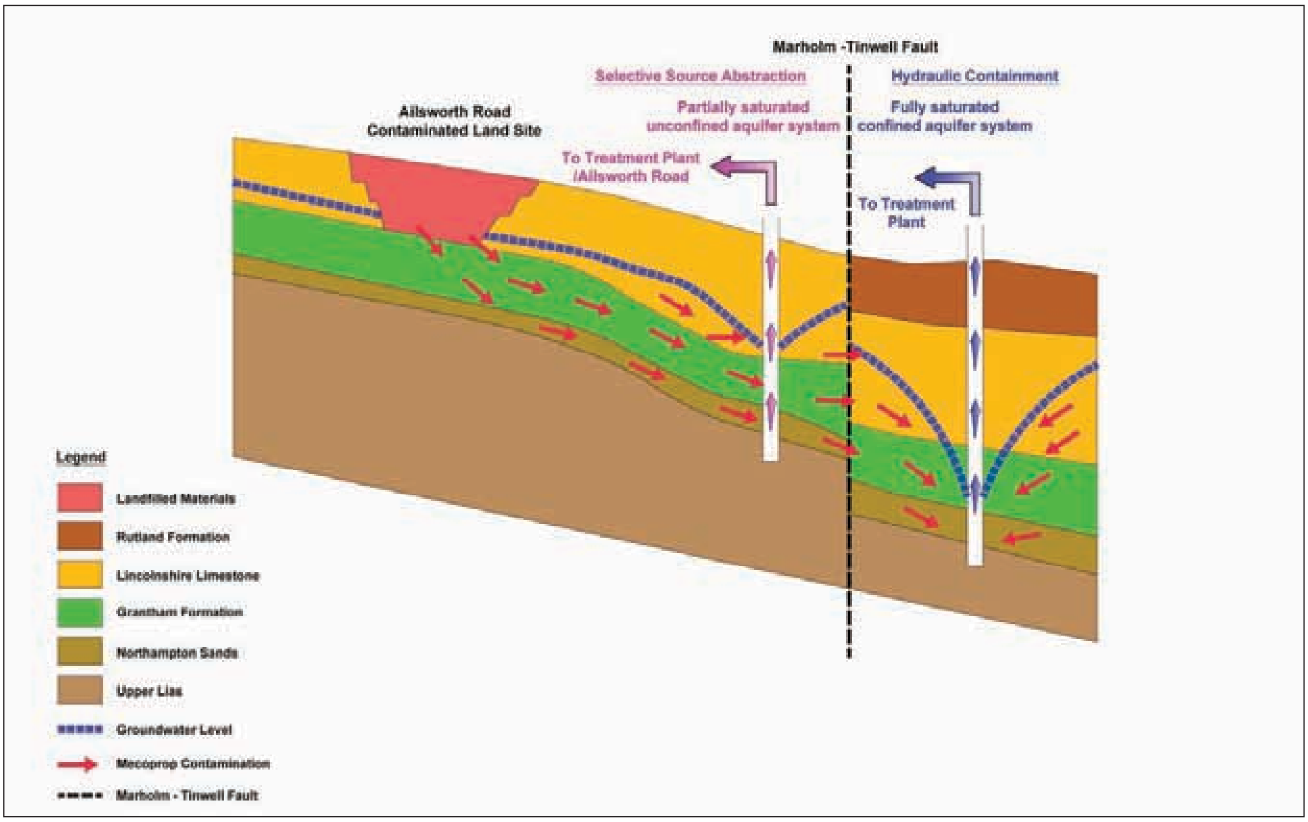
The clear objective of the remediation is to overcome the effects of groundwater pollution from Ailsworth Road and Ben Johnsons Pit. The two contaminant plumes, referred to as Pathway 1 and Pathway 2, already extend over an area some 8 km2 (**Figure 1**).

Because of their devastating effects on the water environment, the landfills have been formally determined to be Contaminated Land (Special Sites) under Part IIA of the 1990 Environmental Protection Act. Because the original polluter cannot meet the cost of the remediation works, the responsibility has fallen to the EA, funded by tax-payers. Helpston is currently the EA's largest self-funded remediation project.

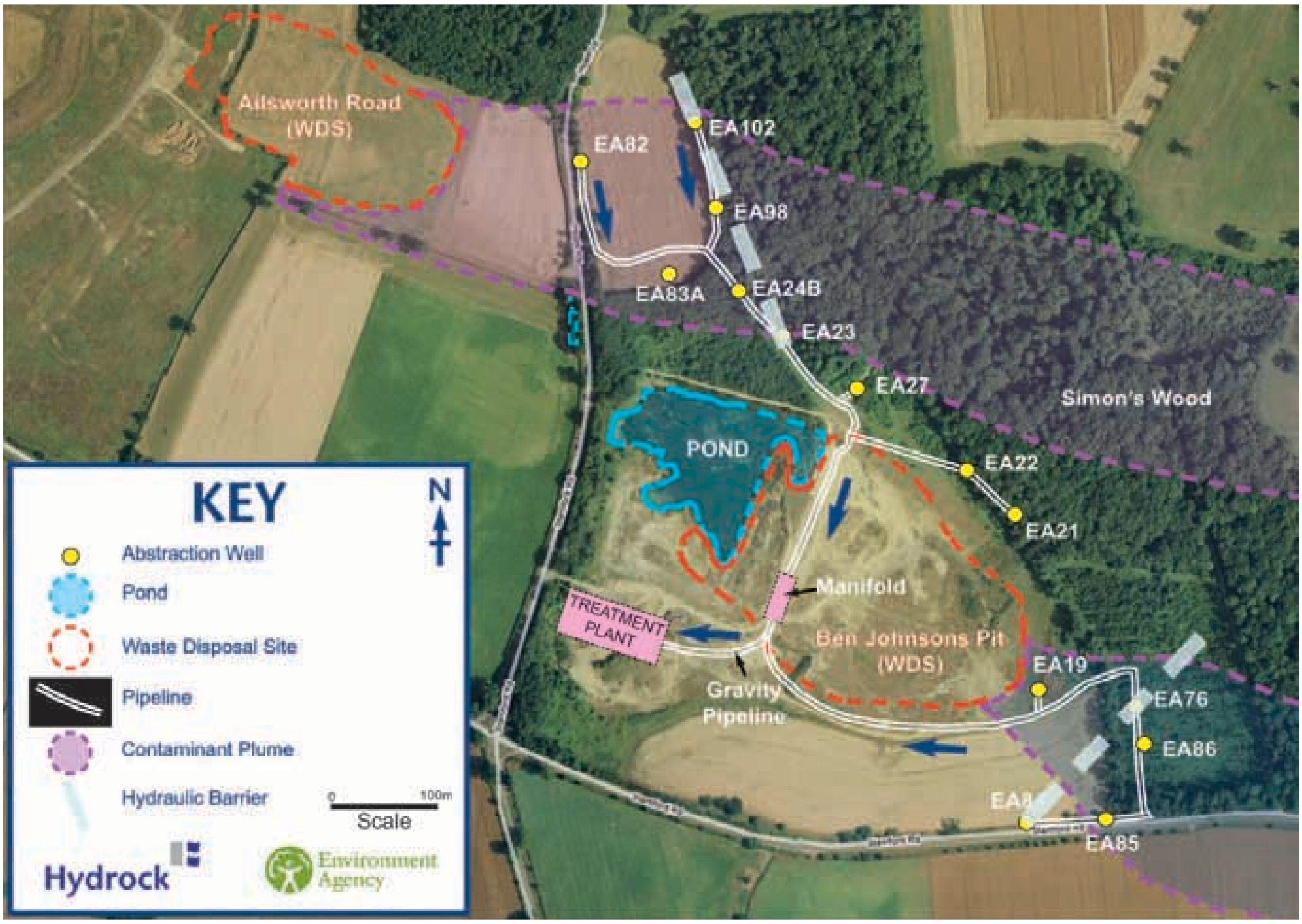
In 2008, Hydrock was appointed to continue remedial works required to deal with this major pollution issue. Whilst many aspects of the problem are extraordinarily complex, the remediation strategy is straightforward: to halt the progress of the two pollution plumes, accelerate remediation at each of the former landfills, and monitor the dispersion of the plumes that have already formed.



▲ **Figure 1: Plan mapping landfill sites, plumes, abstraction and the groundwater treatment plant**



▲ **Figure 2: Hydraulic Barrier schematic – Cross Section Conceptual Model**



▲ **Figure 3: Hydraulic Barrier schematic – Aerial photograph**

THE HYDRAULIC BARRIER

Eastwards migration of the contaminant plumes has been successfully stemmed by the installation of two lines of groundwater abstraction boreholes to the east of the landfills (**Figure 1**). Pumping water from the boreholes forms a series of overlapping cones of depression in the water table which creates a hydraulic barrier to contaminant migration (**Figures 2 and 3**).

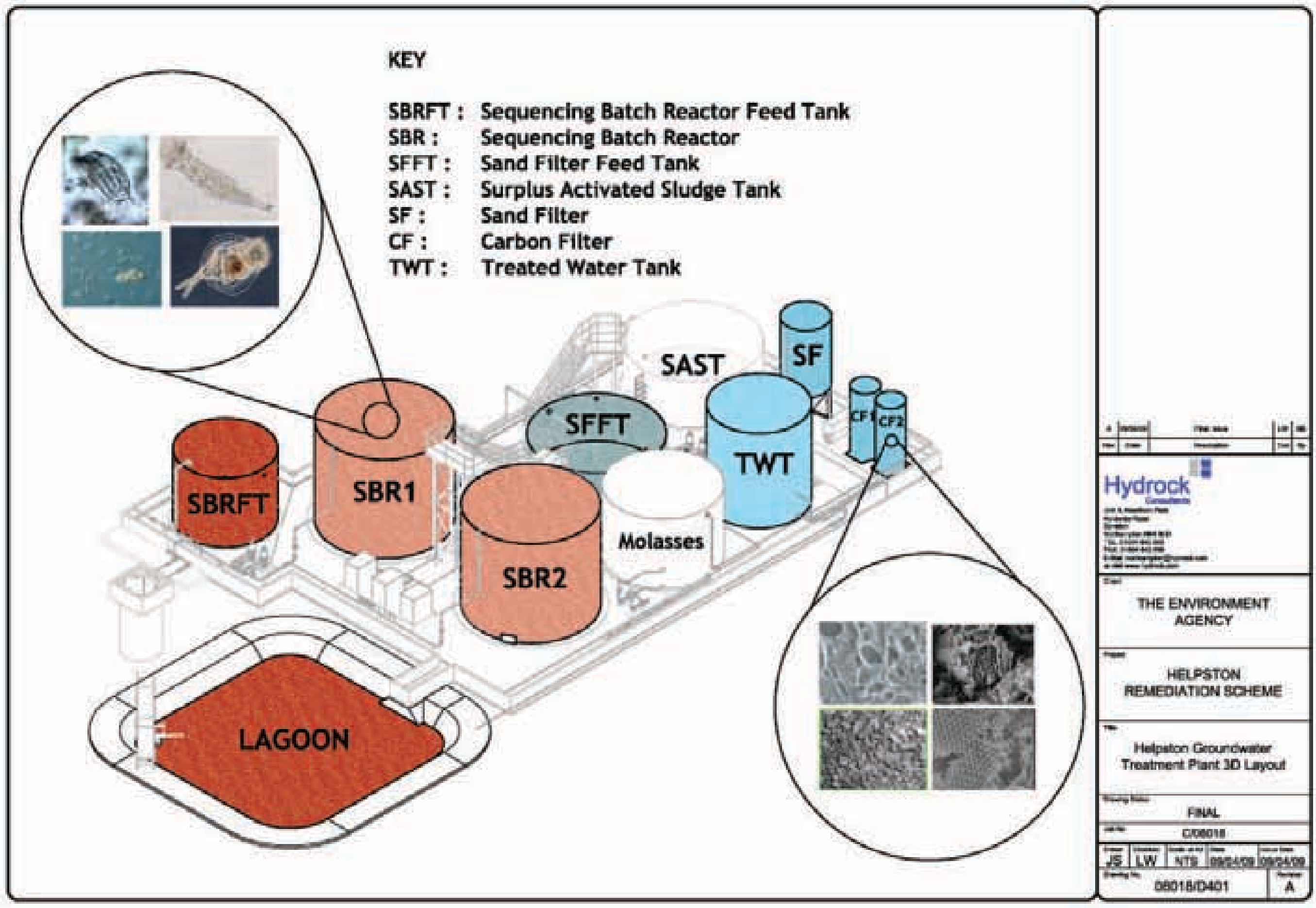
This conceptually simple solution is made difficult by an extremely complicated geology, wherein the rocks are highly stratified and extensively faulted. It is these faults that create the pathways for the plume, because they juxtapose slabs of permeable rock against each other. An additional challenge is that the silt in parts of the aquifer constantly clogs pumps and pipelines. The net effect is that pumping rates are small and boreholes need to be closely spaced in order to maintain hydraulic containment.

Containment was first achieved on Pathway 1 in December 2008, and by early 2011 hydraulic containment of Pathway 2 was also in place. The water from the hydraulic barriers is pumped to a treatment plant that is operated and maintained by Hydrock (**Figures 3, 4** and **5**). The plant operates 24 hours a day throughout the year. Through a system of sequence batched reactors, the water is biologically treated to remove mecoprop and ammonia (**Figure 4**) which make up the principal contaminants present in the groundwater. Of the two, ammonia is the most difficult to treat, especially in the colder weather. The treated effluent is discharged to a nearby pond, subject to limits set in a discharge consent granted by the EA.

CONCEPTUAL MODEL

These practical solutions are underpinned by detailed hydrogeological assessment, which has included the building of complex mathematical groundwater models of the two plume systems. The models have helped to determine the time required for the mecoprop to potentially reach critical receptors such as private abstractions south-east of Pathway 2 (**Figure 1**) and how long it will take for the pollution to fully dissipate, given the remediation strategies that might be applied.

A particular value of groundwater modelling is the way that it pinpoints uncertainties in our understanding the fate of contaminants as they move from the landfill source



▲ **Figure 4: Treatment plant process schematic** to the receptors. For example, modelling the Pathway 2 plume from Ben Johnsons Pit initially showed that the aquifer was unable to accept all infiltration through the waste, indicating possible migration of contaminated groundwater across a major fault. Similarly, whereas the model predicts that, by now, mecoprop should have been observed at the private abstraction boreholes south-east of the Pathway 2 plume, it has yet to be recorded, indicating a possible loss of contaminant to surface waters.

SOURCE REMOVAL

An obvious solution is to remove the mecoprop at source, but that is difficult to achieve without removing or treating hundreds of thousands of tonnes of waste material in the landfills. Working closely with the Environment Agency, Hydrock has undertaken a number of trials at the landfills to see if the mecoprop can be degraded in situ using air injection or flushed out through water injection and abstraction. This air injection strategy is based on the fact that mecoprop breaks down readily when exposed to UV light or oxygen.

Careful investigations undertaken before and after the air injection trial showed a significant reduction in mecoprop. Just the ability to get air into the waste mass ran contrary to most international case-history reports. The experiments have given confidence to source removal proposals, and it is hoped that these can significantly reduce the overall remediation timeframes of the project.

▲ **Figure 5: Treatment Plant**

ECONOMIC REALITY

In these straitened times the EA has to count every penny and the cost-effectiveness of the Helpston project is constantly under review. In parallel with the Helpston remediation, the EA is developing a methodology to determine the value of groundwater, based on issues such as its local importance for water supplies and the cost of replacing it from alternative sources. The determined value can then be compared with the Helpston remediation costs as the basis for objective decision-making about the future strategy for the project.

The decision in the 1980s to deposit pesticides in a landfill above a major aquifer has proved to be a costly mistake. Faults that were supposed to act as natural barriers to contaminant migration turned out to be highly conductive, resulting in groundwater pollution on a regional scale.

However, this may be a story with a happy ending. Hydraulic containment of Pathway 1 and Pathway 2 has been achieved, and the site team are working hard to ensure that these are maintained to halt the further spread of contamination. Meanwhile, Hydrock is working with the EA to deal with the pesticides at source, and so far, results have been extremely encouraging. It may be some years before Hydrox is back on the market but we are heading in the right direction. ES

From a background in hydrogeology, **Eric Cooper** has developed a specialist expertise in managing the risks associated with contaminated land and groundwater. During his 30 year career, he has been Project Director of some of the most challenging land regeneration schemes in the UK.

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Contaminated land remediation technologies – context, current application and future development

Professor Philip Morgan
reviews the relationship between technology and contaminated land treatment.

The effective management of historically contaminated sites is key to ensuring that such land does not have detrimental effects on the wider environment and that it can be brought back into use. Remediation often plays a key role in achieving these aims.

This review provides a perspective on current approaches to remediation of historical soil and groundwater contamination, and highlights likely short- to medium-term developments. The focus will be on the UK market, although the approaches and techniques are widely applied elsewhere.

WHAT IS REMEDIATION?

Of the various definitions available, the following highlights a number of key concepts that underpin current best practice in defining the requirement for, selection of, and application of remediation: "action taken to prevent or minimise, or remedy or mitigate the effects of any identified unacceptable risks from contamination"[1]. Since remediation is undertaken to reduce risks levels from unacceptable to acceptable, evaluation of risk must be based on quantitative risk assessment, which will also help to define clear remediation objectives and the basis for verifying performance.

Underpinning contaminated land risk assessment is the concept of contaminant linkages (also termed pollutant linkages). A contaminant linkage exists when there is:

- a source, for example soil or groundwater containing elevated concentrations of organic or inorganic contamination that has arisen from human activity;
- a receptor that could be harmed by the contamination, such as human health or property, groundwater, surface water bodies, or ecosystems;
- a pathway, i.e. a means by which the contamination can move from the source to the receptor. Examples include direct contact with or ingestion of soil, the consumption of crop plants grown on the site, inhalation of dust or vapours, and movement of dissolved contamination in groundwater.
- only if an operational source–pathway–receptor linkage exists can there be a risk to the receptor, which may require risk assessment and subsequent remediation. In addition, contaminant linkages identify where and how remediation can be targeted to achieve the specified objectives, for example to break linkages completely or reduce receptor exposure to acceptable levels.

REMEDIATION OPTIONS

Breaking pollutant linkages by removing the receptor (e.g. relocating people or moving a drinking water abstraction) is rarely a viable or desirable option. Therefore remediation is usually based on one or more methods that remove or reduce the source, block a pathway, and/or reduce the movement of contamination along a pathway.

There is a wide range of technical options for remediation. From a practical perspective, these techniques can be divided into three categories:

- ex-situ methods, i.e. those that remove contaminated material from the subsurface (by excavating soil or pumping groundwater) and treat it above ground;
- in-situ methods, i.e. those that treat contaminated soil and ground water in place; and
- other engineering methods that do not conveniently fit into the above classes.

A concise summary of the most commonly used remediation technologies is presented in **Table 1** and more detailed information is available from a wide range of sources[2,3]. At many sites, a combination of remediation techniques will be required to achieve the specified objectives. These are known as treatment trains.

▼ **Figure 1: Remediation in action. Photo credit: Philip Morgan**

SELECTION OF REMEDIATION METHODS

Remediation options appraisal is a critical stage in the remediation implementation process and should be proportionate to the scale, complexity and sensitivity of the site1. It should identify viable techniques to achieve the defined remediation objectives, evaluate their relative applicability, and define the optimum remediation strategy, including treatment train combinations.

The criteria employed in the apraisal, and their relative importance, will vary between sites but will often1 include consideration of the following aspects, which are presented in no particular order:

- confidence in technology performance for the case under consideration;
- properties of contaminant and matrix;
- site constraints, such as working space, time available;
- geotechnical requirements;
- cost, both direct costs and longer-term monitoring and maintenance costs (if applicable);
- remediation sustainability;
- the ability of the remediation supplier to provide performance warranties;
- ease of verifying achievement of remediation objectives; and
- specific regulatory requirements.

Remediation sustainability (environmental, economic and social impacts) is receiving increasing attention but will not be discussed here as it is addressed elsewhere in this issue[4].

CURRENT STATE OF REMEDIATION PRACTICE

A recent survey of remediation technologies employed in the UK[2] indicated a strong move away from use of landfill to the wide application of both ex-situ and in-situ technologies. The primary options have been bioremediation, soil vapour extraction (SVE) and groundwater sparging methods, solidification–stabilisation, chemical oxidation, barrier and containment systems, and monitored natural attenuation (MNA). Applications of ex-situ soil washing were reported less commonly but some of those undertaken have been on a very large scale.

Thermal techniques and permeable reactive barriers (PRBs) were significantly less prevalent, the former perhaps due to complexity and relative novelty, and the latter due to long-term monitoring, maintenance and regulatory controls.

The survey also indicated that in-situ technologies are likely to continue increasing in popularity. Bioremediation is already widely used but is being extended to include high-concentration source areas and more cost-effective long-term treatment of large volumes of groundwater. The more aggressive in-situ methods, such as thermal treatment and chemical oxidation, are also attracting increasing interest given their potential to deal with high-concentration source areas and reduce overall remediation timescales. However, their inherent power and consumables costs mean that efficiency improvements are keenly desired by practitioners.

▲ **Figure 2: Digging into the problem of land contamination. Photo credit: Philip Morgan**

On a practical level, the implementation of remediation is increasingly exploiting the constructive benefits offered by recent guidance. Most notable is The Definition of Waste: Development Industry Code of Practice[5], which sets out a practical and auditable approach to assess whether excavated soil and other solid materials at a site are classified as waste or not, and to determine when remediated materials used in land development cease to be waste as a result of the remediation (recovery) operation undertaken. This therefore encourages appropriate re-use of materials, thus minimising waste to landfill, reducing costs, simplifying permitting and improving remediation sustainability.

A further benefit of the Waste Code of Practice is the enabling of cluster remediation[6]. Clusters are designed to facilitate the sustainable remediation and development of a number of sites located in relatively close proximity, through the sharing of a treatment facility located on one of them, the so-called hub. Cluster projects are by definition local and temporary, operating only for as long as the sites are being remediated. The use of fixed-location soil treatment centres is also facilitated by the Waste Code of Practice. As the name suggests, these are permanent, centralised facilities offering one or more remediation technologies to which soil can be sent on a commercial basis.

DEVELOPMENTS IN REMEDIATION TECHNOLOGY

There appears to be a general consensus in the industry[2] that the range of available remediation technologies is sufficient for the great majority of cases, although broadening applications and improving the underpinning science for some technologies would be welcomed, along with improvements in operational efficiencies (e.g. reduced power consumption) and verification methods, particularly for in-situ treatments.

Ongoing developments may also bring some remediation approaches into more common application. Most apparent are thermal techniques designed to improve the performance of in-situ extraction technologies such as SVE and sparging. Efforts are also being made to improve flushing-based techniques, electroremediation and phytoremediation, although their application is likely to remain niche.

Novel remediation approaches will undoubtedly need to offer significant benefits over well-proven options if they are to become widely used. For example, there is interest in using reactive nanoparticles for in-situ treatment of soil and groundwater, although current considered opinion[7] is that the possible benefits will be highly site-specific and that the lack of robust evidence available so far on their potential impacts makes it impossible to give an evidence-based opinion on their environmental acceptability.

CONCLUSIONS

There is an extensive range of remediation technologies in use across the contaminated land industry, both individually and in treatment trains. Certainly, there is a need for improvement in the scientific underpinning, operational efficiency and verification of many techniques. However, experience and practical implementation improvements such as the Waste Code of Practice provide us with appropriate and sustainable solutions for the great majority of sites and the commonly encountered contaminants. Whilst new developments will always be welcomed by the industry, it appears that the coming years will see technical evolution rather than revolution. ES

Phil Morgan is Technical Director for Contaminated Land at The Sirius Group and Visiting Professor or Environmental Biotechnology in the Groundwater Protection and Restoration Group, University of Sheffield.

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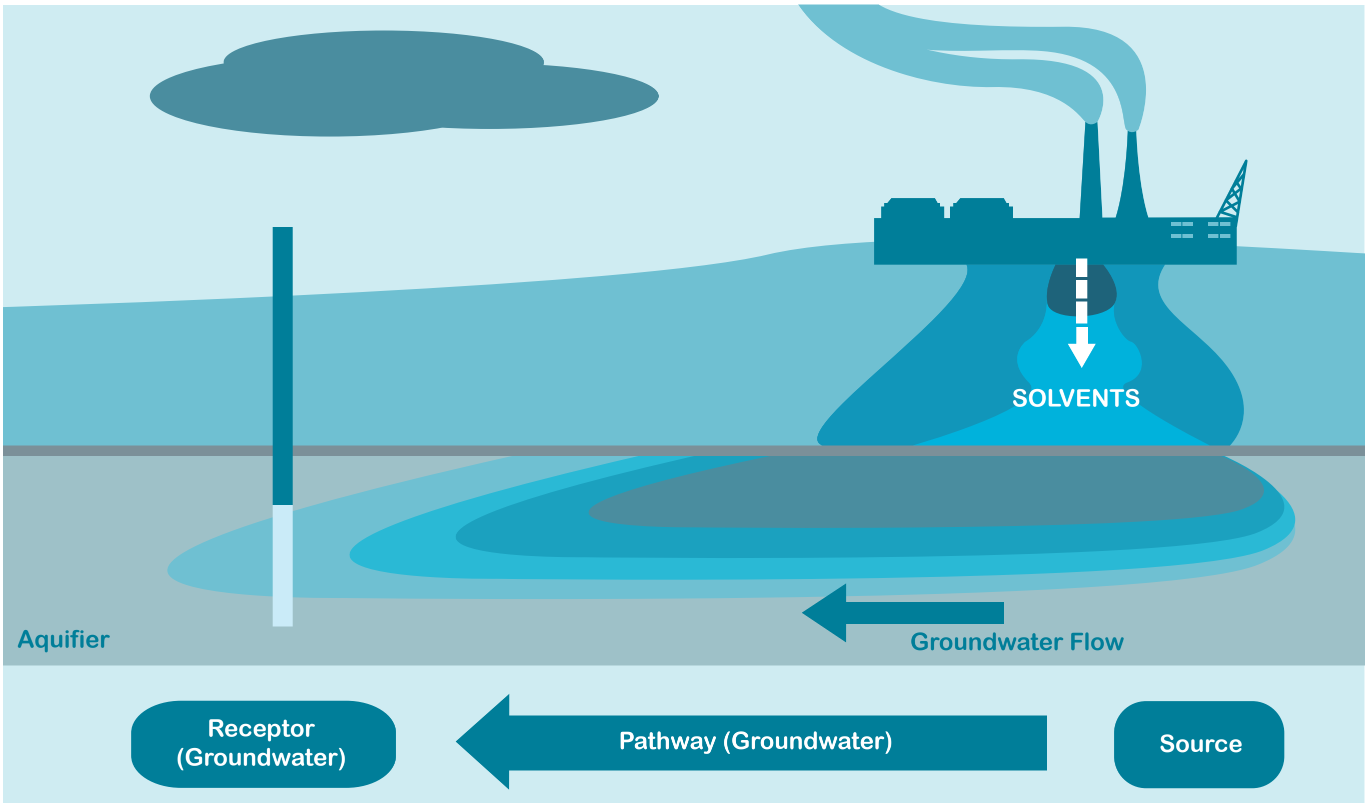
Sustainable remediation

Paul Bardos, **Mark Knight** and **Simon Humphrey** review the history of sustainable remediation and highlight the current issues.

In 1961 the Lower Swansea Valley Project, after many years of campaigning and fund raising, began to investigate how to restore one of the largest areas of post-industrial dereliction in Europe. Today, more than fifty years later, the terms of reference for this project resonate with modern-day themes of sustainable development: "to establish the factors which inhibit the social and economic use of land in the Lower Swansea Valley and to suggest ways in which the area should be used in the future". The entire area has been transformed by the large-scale restoration in the valley from the late 1960s. From a contemporary point of view it is interesting to see mention of the economic and social aspects of sustainability, but no mention of environmental or human health protection. Of course, some of the environmental consequences of the dereliction were plainly visible in the absence of trees and strangely coloured river, and much early effort involved finding out what might be encouraged to grow, and how.

UNDERSTANDING CONTAMINATED LAND PROBLEMS

Developing ideas of what might constitute unacceptable levels of contamination were formulated in the UK from the mid-1970s under the aegis of the Interdepartmental Committee for the Redevelopment of Contaminated Land, as an increasing number of redevelopment projects encountered land-contamination problems. From the late 1970s and early 1980s there was increasing global recognition of the potentially serious consequences of land contamination, triggered by major incidents in several countries where houses were built on former industrial waste disposal sites, such as Lekkerkerk in the Netherlands and Love Canal in the USA. Over the next 20 years there was a substantial international effort to develop the tools necessary to understand the significance of contaminated land problems and deal with them. There was a high degree of international co-operation through collaborative projects funded by the EU, and conferences and exchanges supported by NATO. Two broad concepts emerged: the use of risk assessment to determine the seriousness of the problems, and the use of risk management to mitigate problems found to be significant. For a risk to be present there needs to be a source (of hazardous contamination), a receptor (which could be adversely affected by the contamination) and a pathway (linking the source to the receptor). A receptor might be human health, water resources, a built construction, ecology or the wider environment. In the UK this combination of a source–pathway–receptor is referred to as a pollutant linkage (see **Figure 1**).



▲ **Figure 1: Illustration of a source-pathway-receptor pollution linkage**

Risk assessment focuses on identifying which combinations potentially exist, and if so whether they are likely to be significant (i.e. cause harm). Risk management focuses on breaking the pollutant linkage, either by controlling the source (e.g. extracting the contamination from the subsurface); managing the pathway (e.g. preventing migration of contamination); protecting the receptor (e.g. avoiding sensitive land uses) or some combination of these components. The terms remediation and risk management are now largely synonymous. Around the millennium these broad concepts were crystallised in Europe as risk-based land management by a collaborative European project called CLARINET (Contaminated LAnd Rehabilitation Network for Environmental Technologies), and in the USA as risk-based corrective action by ASTM International (the US equivalent of the BSI).

In terms of sustainable development, contaminated land remediation was generally recognised to be a positive step, almost automatically considered sustainable. It brought land back into use, dealt with pollution problems and reduced development pressures on greenfield sites. In some countries, such as the UK, there was an idea that remediation should not take place without some regard to its costs, and frameworks and tools for cost–benefit analysis (CBA) were developed. However, the broader impact of the remediation process itself on environment, economy and society was not a major factor in decision-making. This broader impact was to some extent epitomised by the question of whether it is really worth expending tens of litres of fossil-fuel equivalent to recover 1 kg of hydrocarbon from a tonne of soil. Of course this is an unfair question, as it depends on the level of risk, but its symbolism is important. A more contentious debate currently taking place is whether it is really sustainable to treat land so that the modelled excess lifetime cancer risk to an individual exposed to contamination over a long period is reduced to, say, one in 1,000,000 by using earth-moving equipment where the risk of worker fatality due to workplace accident is, perhaps, one in 10,000 in a working year. This may not be a true comparison of like with like, but illustrates a real difficulty in identifying what is sustainable, which is that the winners and the losers are not necessarily the same. The issue of voluntary and involuntary risk are also relevant in this analysis, as are the fact that the worker gets a direct benefit (a salary) for attending the remediation job, while the individual resident experiences no direct benefit in return for accepting their potential exposure to residual levels of contaminants in the land.

Sustainability has a real impact. An early casualty of the failure to consider sustainability in sufficient depth was the early Dutch policy of multi-functionality. The idea behind multi-functionality was inter-generational sustainability, in other words, if contaminated land was to be remediated it was most sustainable to treat the site only once. Therefore the remediation work should be sufficient to allow any future land use, so that no future remediation would be needed for that site. The multi-functional policy was largely predicated on the idea that contaminated sites were not numerous, but it soon became clear that the economic resources needed could not be sustained by Dutch society, in a country where as much as 10 per cent of the land surface was suspected to be contaminated. Later on the Netherlands, like other countries, took a functional (fit-for-purpose) approach, treating sites only to the extent needed for the next envisaged land use, so that land intended for an industrial land use did not need the same amount of treatment as a garden where food could be grown. Today nearly all countries with a developed policy take a functional approach to setting remediation targets.

So what is the current situation, and what is sustainable remediation? As for risk management, there is a substantial international collaborative effort to improve the sustainability of the approaches to managing contaminated land, with a range of initiatives in the UK, elsewhere in Europe, North and South America, and Australasia. The debate centres on how sustainability benefits can be assessed and maximised and how negative impacts can be avoided or limited. There is a remarkable degree of consensus across these initiatives about what a vision of sustainable remediation might be. In broad terms concepts of sustainable remediation are based on the achievement of a net benefit overall across a range of environmental, economic and social concerns that are judged to be representative of sustainability.

IS REMEDIATION ALWAYS SUSTAINABLE?

It is clear that remediation is actually not automatically sustainable. The cure should not be worse than the illness. Remediation work can have its own environmental consequences, such as the use of resources and impacts on water and air; its own economic consequences, such as on the viability of businesses or projects; and its own social consequences, such as risks to site workers or impacts on road traffic. Remediation clearly can also have direct benefits, including the reduction of pollutant loadings in the environment; the protection of human health and the enabling of new economic use of land. It can also have wider benefits, including an uplift in surrounding property values, resource recycling or the creation of new public amenity. What is clear is that the balance of consequences is highly site specific and project specific, and also that it is often linked to the project or business goals that require the remediation to take place. For example, for a site regeneration project involving new buildings and new construction, early consideration of sustainability can have a major effect on reducing negative consequences by avoiding unnecessary use of energy and material and financial resources through carefully integrating remediation and regeneration design.

Various international initiatives are developing tools so that sustainability in remediation can be assessed, managed and enhanced. The EU-funded HOMBRE (HOlistic Measurement of Brownfield Regeneration) project has a particular focus on developing synergies between brownfield regeneration and other environmental services, to improve the sustainability of remediation and regeneration. Examples include combining groundwater treatment with in-ground heat storage, or the production of biomass from land areas undergoing rehabilitation. The EU-funded Greenland (gentle remediation of trace element contaminated land) project is investigating how plants and other low-input approaches to remediation can improve sustainability in remediation.

The Sustainable Remediation Forum in the UK (SuRF-UK) has been enormously influential in this debate, and has already produced a framework and tools to support decision-making in a way that ties in well with existing good practice guidance for risk assessment and management. Currently, SuRF-UK is working to extend this by providing case studies and practical guidance for sustainability assessors. The framework advocates a tiered approach to the assessment of sustainability and emphasises that the decision-making effort should be proportionate, with decisions based on the simplest approach that demonstrably provides a robust outcome. .The assessment tiers can range from simple qualitative appraisal, through multi-criteria analysis, to more complex assessments such as monetised CBA.

CBA is a powerful tool that allows the direct comparison of very different impacts using a common denominator that everyone is familiar with – money. However, conventional CBA approaches are limited in that only a few of the key sustainability indicators that should be assessed as part of a sustainability appraisal can be easily monetised. Economic indicators are relatively straightforward and a number of environmental impacts, such as carbon dioxide emissions, groundwater resources and habitats, can be ascribed a range of monetary values. However, the monetisation of other environmental indicators and the majority of the potential social impacts are not usually possible so these are often excluded by practitioners from CBAs.

There is an emerging school of thought that financial quantification can be made, albeit at a high and sometimes crude level, for all social, environmental and economic impacts, and there should be no exclusions from the CBA process (except for factors that are demonstrably irrelevant or unchanged). This theory is based on the application of values rather than direct measurable financial costs. Examples of this have abounded in financial accounting for many decades in measures of goodwill, commonly referred to as brand value and reputation. All of these remain broadly intangible, but are clearly well understood by markets and investors when placing a valuation on a company based on its share value – itself a function of many direct and indirect costs. Potentially the same principles can be applied during CBA for a remediation project to test its sustainability in terms of the value it may create or destroy for participating companies, rather than focusing on a strictly monetised approach. HOMBRE seeks to apply this kind of a wider value-based approach throughout the urban land cycle as a tool for managing sustainable urban development and providing robust and long term solutions to problems of dereliction. **ES**

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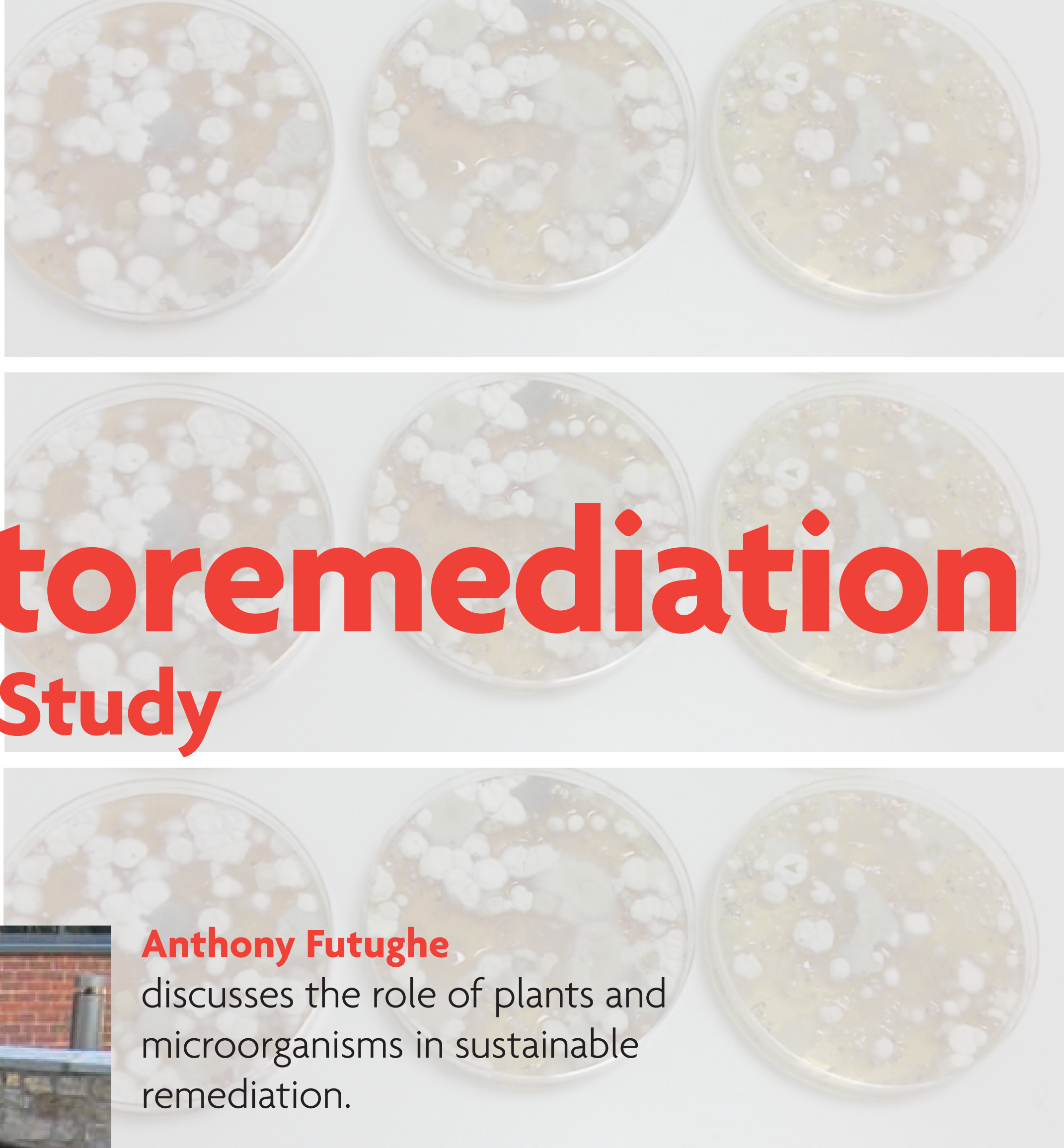
CASE STUDY



Phytoremediation
A Case Study

Anthony Futughe discusses the role of plants and microorganisms in sustainable remediation.

With the advent of the Industrial Revolution, numerous hazardous contaminants have been introduced by people into the soil environment[1]. These pose serious environmental risks, including from surface and groundwater contamination, making remediation essential[2]. Remediation involves the removal of these toxic pollutants from the contaminated area.

Currently, the management of contaminated soil and groundwater is a major global environmental issue. In Europe alone, it is estimated that over 80,000 sites have been cleaned up over the past 30 years, there are at present approximately 250,000 sites with contaminated soil requiring clean-up, and potentially polluting activities are estimated to have occurred at nearly 3.6 million sites[3,4]. Various traditional methods of treating contaminated land and groundwater, such as excavation and land filling, biological treatment, physico-chemical treatment (washing), thermal desorption, and isolation may not be the most sustainable options. They are often energy intensive, generate waste, and produce greenhouse gases through the use of heavy-duty construction equipment[4,5,6]. In addition, complete contaminant removal is infrequent and habitat quality is negatively impacted. This has led to a significant increase in research into the development of alternative in-situ and ex-situ treatment technologies for soil and water remediation[7].

STEPS TOWARDS SUSTAINABLE REMEDIATION

The most promising development is sustainable remediation. According to SuRF-UK, sustainable remediation is defined as "the practice of demonstrating, in terms of environmental, economic and social indicators, that the benefit of undertaking remediation is greater than its impact, and that the optimum remediation solution is selected through the use of a balanced decision-making process"[8]. This is becoming increasingly important as many sectors look to minimize their environmental impact.

Phytoremediation is one of the sustainable remediation alternatives to traditional remediation technologies9. Phytoremediation uses hyperaccumulators – plants, such as *Brassica juncea*, that take up larger amounts of contaminants than other plants. Hyperaccumulators extract, degrade, contain, or immobilize contaminants in soil, groundwater, and other contaminated media. This green technology can be applied to both organic and inorganic pollutants present in ecosystems10,11. The phytoremediation mechanisms used to treat contaminated soil in situ are listed in the **Table 1**.

Treatment	Description
Phytoextraction	Removal and concentration of heavy metals into harvestable plant parts.
Phytodegradation	Degradation of contaminants by plants and their associated microorganisms.
Rhizodegradation	Absorption of heavy metals by plant roots from contaminated water.
Phytostabilization	Immobilization and reduction in the mobility and bioavailability of contaminants by plant roots and their associated microorganisms.
Phytovolatilization	Volatilization of contaminants by plants from the soil into the atmosphere.

Table 1: Mechanisms of phytoremediation

The various mechanisms of phytoremediation can treat a wide range of contaminants, including heavy metals, volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), petroleum hydrocarbons, radionuclides, and munitions, although not all mechanisms are applicable to all contaminants. Phytoremediation may take longer than other technologies to treat a site, because several growth cycles may be needed, there is also a risk of the plants to re-release some of the contaminants upon decomposition and also enter the food chain. Thus, harvested plant biomass should be classified as hazardous waste and as such, should be disposed off appropriately in a designated landfill. Phytoremediation, however, has the potential to be less expensive than excavating and treating large volumes of soil ex situ[13]. Licht and Isebrands (2005)[14] have acknowledged the potential inclusion of bioenergy production in the economic assessment of phytoremediation (crops) and also carbon dioxide abatement[9].

BIOSURFACTANTS ENHANCING PLANT PERFORMANCE

A case study on sustainable remediation using phytoremediation techniques investigated the impact of biosurfactant (rhamnolipid) produced from a strain of *Pseudomonas aeruginosa* NCIMB 8626 on the growth of *Brassica juncea* and the plant's uptake, transfer factors and removal of diesel (benzo[a]pyrene) and Pb from contaminated soil during phytoremediation. Biosurfactants are natural surface-active products that reduce the surface tension between two liquid phases, enabling the uptake of hydrophobic substrates by plants and microorganisms. It is also a chemical ligand which has a strong affinity for metals such as Pb, Cd and Zn through its single carboxyl group (Ochoa-Loza et al., 2001)[15], and has been used in soil washing of heavy metals over recent years[16,17,18,19]. Transfer factors has been defined as the ratio of contaminant concentration in plant material compared with that present in contaminated soil[20]. In addition, the soil indigenous microbial populations were monitored. The results indicate that biosurfactants might be useful for effective sustainable remediation of diesel pollution (in particular, benzo[a]pyrene) and lead-contaminated sites using phytoremediation. Biosurfactants enhanced the growth of *B. juncea*, contributed to the negligible increase in the microbial population and may have influenced the degradation of diesel through emulsification by microorganisms, especially bacteria, which dominated the soils of the treatment group. There was a significant decrease ($P < 0.05$) in the dry biomass of [B. juncea] from the control group compared to the treatment group. Plants from treatment group with biosurfactant accumulated more Pb into its tissue than plants from control group. The presence of biosurfactant in the treatment group also increased Pb availability and its transfer factors compared to the control group.

THE FUTURE

The case study was a novel approach to cleaning up contaminated sites, thus showing that enhanced phytoremediation can potentially be a valuable addition to sustainable remediation. The use of plants and biosurfactant microorganisms to degrade, accumulate or transfer contaminants is solar driven, well-suited to large areas of surface contamination, aesthetically pleasing, has favourable public perception and is relatively easy to apply. It also improves soil quality, prevents erosion, eliminates secondary air- and-water-borne wastes, including greenhouse gases, and is relatively cost effective[21,22,23].

The future of phytoremediation is in the advancement of molecular biology, which would allow the production of plants tailored specifically for some tasks by isolating genes from plant, microorganism, or animal sources[24,25] that enhance remediation of contaminated soil. A number of experiments have shown the feasibility of engineering higher extractive and degradative abilities in plants via genetic modification.[26,27,28,29]. The improvement of plants by genetic engineering with biosurfactant could open up new possibilities for sustainable remediation of contaminated land. **ES**

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Is current legislation fit for purpose?

Valerie Fogleman discusses the impacts of Part 2A of the Environmental Protection Act on remediating contaminated land.

In 2000, the UK Government introduced a regime to remediate contamination from past pollution incidents. The regime, which is set out in Part 2A of the Environmental Protection Act 1990, imposes liability on a person who "caused or knowingly permitted" land to be "contaminated land" to remediate the contamination. If such a person (called a Class A appropriate person) cannot be found after a reasonable inquiry, the owner or occupier of the land (called a Class B appropriate person) is liable.

Part 2A is merely a skeleton; the flesh of the regime is contained in statutory guidance (SG) that was revised in April 2012. The SG, which has been reduced in size but is still 69 pages long, provides details of how local authorities should inspect their areas for contaminated land, carry out risk assessments to determine whether the land is contaminated land and if it is, how such land should be remediated and the relevant costs recovered.

Twenty pages of the SG set out the liability system. This section includes details of the identification of persons who are liable for remediating each "significant contaminant linkage", for which more than one may exist at a site, tests by which appropriate persons may be excluded from liability, the apportionment of liability between the remaining persons in a liability group after application of the exclusion tests, and the attribution of liability between liability groups if more than one such group exists at a site.

The revised SG states that enforcing authorities, which include the Environment Agency (EA) for a sub-set of contaminated land called special sites, "should seek to use Part 2A only where no appropriate alternative solution exists". The other solutions mentioned are planning, voluntary remediation, building regulations, regimes for waste, water and environmental permitting, and the Environmental Damage Regulations.

According to the impact assessment accompanying the revised SG, "significant uncertainties" in the former SG "has forced developers and other businesses into wastefully expensive remediation, which creates a deadweight burden on the UK economy [and which] has also led to poor value for taxpayers' money used to fund public sector land remediation projects". This statement is no doubt true. However, the real reason that Part 2A has led to poor value for taxpayers' money is its enforcement-unfriendly nature and the complexities of its liability system, neither of which have been revised.

Part 2A has had successes. It has led to the voluntary remediation of contamination by companies in order to avoid liability under the regime. It could well be argued, however, that any liability system for remediating contaminated land would have had the same effect; an effect that lasts only so long as the regime is perceived as a threat. The lack of robust enforcement of Part 2A has minimised this threat.

COMPLEX ENFORCEMENT REGIME

The lack of enforcement has its roots in an enforcement-unfriendly regime, which is so complex that it can never achieve its objective of "dealing with unacceptable risks posed by land contamination to human health and the environment".

Part 2A requires approximately 300 local authorities to prepare individual strategies to inspect their areas for contaminated land and then to carry out the inspections. If they find contaminated land, they have a duty to enforce the regime. The revised SG, however, recognises that only in "a minority of cases [is there a] sufficient risk to health or the environment for … land to be considered contaminated land". A major defect of Part 2A, therefore, is the large number of enforcing authorities.

This defect has resulted, among other things, in the absence of a national list of sites that pose an unacceptable risk to human health and the environment, and which should therefore be remediated. Perhaps more seriously, individuals in each local authority must understand the complex regime in order to implement it. A more prudent approach, especially in this economic climate, would be for the EA to be the sole enforcing authority. Not only would this save costs but the EA, in consultation with local authorities, could prioritise sites to be remediated in the whole of England and Wales in order to ensure remediation of the most contaminated sites first.

Most of the revisions to the SG are to the criteria for determining whether land is contaminated land. There would be no need for such detailed criteria, however, if the EA was the sole enforcing authority and had the power (not the duty) to determine, subject to a specified threshold, whether land contamination poses an unacceptable risk to human health and the environment. The Agency has discretion in issuing works notices under the Water Resources Act 1991 and other legislation implemented by it. It simply leads to unnecessary complexities for Part 2A to be different.

Other aspects of Part 2A seem designed to deter its enforcement. For example, an enforcing authority cannot recover the costs of investigating potentially contaminated sites from a person who is subsequently determined to be the appropriate person; such costs remain with the authority.

Further, an enforcing authority is barred from issuing a remediation notice if it is satisfied that "appropriate things are being, or will be, done by way of remediation" by the person on whom it would issue a notice. This prohibition has been interpreted so broadly by some authorities that remediation has not yet begun at some sites despite their designation as contaminated land many years ago.

Still further, the 23 grounds of appeal to a remediation notice almost ensure that any notice will be challenged, or will be threatened to be challenged.

In effect, Part 2A deters authorities from determining that sites are contaminated land because if they do, they must enforce the regime, and in many cases will inevitably incur high technical and legal costs which they are unlikely to recover.

COMPLEX LIABILITY SYSTEM

Another major defect of Part 2A is the overly complex nature of its liability system. This complexity does not, however, result in a fair system, which it purports to do. No system that imposes retroactive liability for remediating contamination on a person who was not been negligent when the incidents causing the contamination occurred can be fair, especially when that person may have followed what was then best practice in their waste-disposal activities. Neither is it fair to impose liability on a person, such as a homeowner, due simply to their status as the owner of contaminated land. The purpose of a liability system in a regime to remediate historic contamination such as Part 2A is simply to channel liability for remedial costs to persons that are connected to contaminated land instead of to the taxpayer.

The revised SG, however, continues to insist that the liability system is fair. For example, it describes the exclusion tests as "intended to establish whether, in relation to other members of the liability group, it is fair that relevant persons should bear any part of that responsibility". This statement ignores the additional fact that a system that imposes modified joint and several and retroactive liability cannot be fair. Part 2A is such a system. Assume there are five persons in a liability group and four are excluded because they satisfy the exclusion criteria. In such a case, the remaining person, who cannot be excluded under the liability system, is 100 per cent liable for remediating the contamination.

Some exclusion tests go even further. For example, a person who consigned waste to another person "under a contract under which that other person knowingly took over responsibility for its proper disposal or other management" is excluded from liability regardless of whether the consignee can be found. Many former landfill operators (often lessees of land previously used as quarries) have, however, ceased to exist. Further, county authorities historically owned and operated many landfills. Whilst it is not fair for persons who lawfully disposed of waste to be liable for its remediation, it cannot be fairer for taxpayers with no connection to the land to pay the cost. Yet this is precisely the result of the exclusion test.

The revised SG retains the approach of sub-dividing contaminated land into multiple areas, stating that an enforcing authority should take into account, among other things, the ownership of the land. This approach, which led to the determination of 109 areas of contaminated land on a housing estate in east Manchester (one for each of the houses on the former waste disposal site), is unnecessarily costly in time and money. Part 2A provides for more than one significant contaminant linkage to be on contaminated land. It does not make sense to require the determination of a large number of areas of contaminated land at one location.

It is also not sensible for Part 2A to impose liability when there is significant harm, or a significant possibility of such harm, to private property such as buildings, crops, livestock or pets. Inclusion of private property in a regime to protect the public from an unacceptable risk of harm to human health or the environment simply results in unwarranted complexities.

Further, whereas it is right and proper that a person who caused significant harm or a significant possibility of such harm to an ecologically diverse site protected under EU and national legislation to be liable for its remediation, the remediation measures set out in the SG are not designed to restore the ecology of such sites. The SG does not explain why mere remediation is considered to be adequate.

In conclusion, Part 2A has never been fit for purpose and, despite the revised SG, is still unfit. Instead of an effective remediation regime, Part 2A is the worst of all worlds: an overly complex liability system in an enforcement-unfriendly regime that has resulted in taxpayers paying a large proportion of the costs. ES

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NEW CL:AIRE Remediation Technologies E-Learning Suite 2012

CL:AIRE in association with the Environment Agency and leading industry experts has developed an interactive e-learning suite. It provides information and training on key aspects of undertaking options appraisals and selecting, designing, implementing and verifying different remediation technologies. These courses are aimed at foundation and intermediate level.

The 10 courses comprise the following subjects:

Options Appraisal; Monitored Natural Attenuation; Permeable Reactive Barriers; Air Sparging/Soil Vapour Extraction; Ex situ Bioremediation; Chemical Oxidation; Stabilisation/Solidification; In situ Bioremediation; Soil Washing; In situ and Exsitu Thermal Desorption.

Course Structures

Each course typically consists of four modules (five modules for thermal desorption) and two assessments delivering approximately 4 hours of learning for each course.

Option Appraisal consists of:

- Introduction to Options Appraisal
- Overview of Remediation Technologies
- Key features in Options Appraisal and
- How to conduct an Options Appraisal

The 9 remediation technology courses comprise:

- Introduction to the technology
- Design
- Implementation and
- Verification

Module 1 comprises a recommended reading list for self-study and modules 2, 3, 4/5 are individual podcasts consisting of a presentation with narration. The first assessment is set after module 1 to ensure that you have undertaken the self study and understood the basic principles and the second is required on completion of the remaining subject modules. On completion of all the activities and passing of both assessments, a personalised PDF certificate will be issued automatically for your Continuing Professional Development.

Cost

Each Course (comprising 4/5 modules) costs **£50 + VAT** (Members 15% discount)

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