RSC INTEREST GROUP
TOXICOLOGY

Toxicology Topics in Brief
Land Contamination

Introduction

This Note outlines the regulation of land contamination in the UK, the risk-based methodology employed to deal with it and the role of chemists and chemistry in this regard. Sources of further information are also given, for those who require it. It may be useful to those with a particular interest in the subject. It replaces the previous RSC Notes on contaminated land, published in 2001, 2009 and 2014.

The UK, along with other industrialised nations, has a legacy of land that contains chemicals and other substances from previous use. These substances may be present due to historic waste disposal practices, leaks or spills and the resulting soil and groundwater pollution can pose potential risks to human health and the environment. In recent years efforts have been made to overcome this situation. This Note outlines some of the measures that have been adopted, both legal and technical, with a particular emphasis on the important contribution of chemists.

Why is Contaminated Land a Problem?

UK government initiatives have encouraged building on previously developed land (so-called “brownfield land”) and have set targets for the building of new homes on such land [NB - not all brownfield sites are contaminated or located in urban areas]. Clearly, such land must be suitable for its proposed use and, if necessary, decontaminated before redevelopment occurs.

There is also specific legislation which requires local authorities to undertake, or oversee, the identification, assessment and treatment of land which is judged to pose an unacceptable risk to humans and the environment, under its present use. The legislation contains specific requirements relating to liability, with polluters, developers and owner/occupiers all potentially having responsibilities.

It is thought that up to 200,000 sites, equivalent to an area larger than greater London, may be contaminated, mainly from past industrial activities. These sites may be affected by various contaminants, for example landfill gas, heavy metals, and organic chemicals with the potential for detrimental impact on human health, groundwater, surface water and ecosystems.

Regulations and Regulators

Part 2A of the Environmental Protection Act 1990

Part 2A provides the current statutory framework for dealing with contaminated land in the UK. Part 2A was introduced via Section 57 of the Environment Act 1995, coming into effect in England and Scotland in 2000 (Wales in 2001) and being subject to some amendment since (see www.legislation.gov.uk). The regime provides for the identification and remediation of “contaminated land”, which is given a statutory definition based on the risks of significant harm to specified receptors or the significant pollution of controlled waters. The precise definition in the Act is "any land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in, on or under the land, that (a) significant harm is being caused or there is a significant possibility of such harm being caused, or (b) significant pollution of controlled waters is being caused, or there is a significant possibility of such pollution being caused".

Further details on how sites should be dealt with under Part 2A are provided in Statutory Guidance, which has recently been revised by DEFRA. A key aspect of the revised Statutory Guidance is that land should be placed in one of four categories, following assessment, principally based on risk. Therefore, different regimes now exist in England and Wales (which are subject to the new guidance), Scotland (which is not subject to the new guidance) and Northern Ireland (where Part 2A has never been implemented).

Under Part 2A, Local Authorities are responsible for the identification of contaminated land, using a risk- based approach, and for ensuring that remediation is undertaken, where necessary. Local Authorities must also maintain a public register detailing the regulatory actions that they have implemented. The Environment Agency has a complementary role, with specific responsibilities such as acting as the enforcing authority for designated special sites. As well as its regulatory role, the Environment Agency has published a great deal of technical guidance for local authorities and practitioners on how to assess and remediate potentially contaminated sites.

Local Authority Planning System

Contaminated land is also a consideration within the Local Authority planning system. When planning permission is sought for the development of a site that is potentially contaminated, the local planning authority will take this into account and may require investigative work (and possibly remediation) to be completed by the applicant.

Developers (applicants) often commission specialist environmental consultants to conduct contaminated land investigations on their behalf. The resulting assessment can then be submitted with the planning application to the Local Authority for approval, assuming that the site is suitable for its proposed use. Although planning permission may be granted on condition that a site is investigated and remediated to the satisfaction of the Local Authority, such work may also be performed prior to submission. The National Planning Policy Framework (NPPF) provides further details on this, as do local planning policy documents (where available).

Contaminant-Pathway-Receptor Linkages

Both Part 2A and the planning regime require a risk-based approach to the management of potentially contaminated sites. A land contamination risk assessment incorporates an assessment of contaminant-pathway-receptor relationships, or “linkages” for a specific end use, in line with the UK’s policy of suitability for use (i.e. land under the intended use is investigated and if necessary remediated to a standard which does not pose unacceptable risks to human health and the environment).

Risk Assessment

As indicated above, decisions regarding the need for and scope of remediation at a potentially contaminated site should be made based on a risk assessment. Such risk assessments are typically carried out by environmental consultants who may be employed either: 1) on behalf of a developer (applicant) who is seeking planning permission for development of a brownfield site; or 2) the Local Authority who is discharging their Part 2A duties and responsibilities. Risk assessments can involve intrusive ground investigations and they may take place over several phases, leading to remediation and validation if a significant or unacceptable risk from contamination is identified.

A “preliminary risk assessment” (PRA) is often performed initially. A PRA typically involves the identification of potential sources of contamination, pathways and receptors (“contaminant linkages”), via the assessment of desk-based information, such as historical plans, geological maps and industrial profiles, along with a site visit. A "conceptual model" is also developed during this stage and a qualitative judgement made concerning the need for further assessment, based on the likely completeness/significance of such linkages.

Where the PRA identifies potentially significant source-pathway-receptor linkages, an intrusive investigation may be carried out to provide quantitative information on contaminant levels at the site, to help assess pathways and risk to receptors as part of a Generic Quantitative Risk Assessment (GQRA). Such an investigation typically involves obtaining soil and/or groundwater samples, via drilling and/or ground excavation, and submitting them for chemical analysis. Reported contaminant concentrations in soil and groundwater are then compared with available Generic Assessment Criteria (GACs) using statistical techniques, if appropriate. If concentrations are particularly elevated then a Detailed Quantitative Risk Assessment (DQRA) can be performed and/or the site identified for remediation. A DQRA may involve the use of computer models to derive Site Specific Assessment Criteria (SSACs), for further comparison with contaminant concentrations, as well as additional investigative activities (e.g., media sampling, bioaccessibility testing, measurement of plant uptake).

As indicated above, a GQRA often involves the comparison of GACs against measured contaminant concentrations in soil. GACs for certain substances have been published by Defra/Environment Agency, in the form of Soil Guideline Values (SGVs), which represent "minimal risk" while other organisations have used the same Contaminated Land Exposure Assessment (CLEA) model used to derive the SGVs, to derive values for other substances. The CLEA model software can also be used by risk assessors to derive SSAC values, as part of a DQRA.

In relation to the assessment of potential risks to groundwater, the Environment Agency's "Remedial Targets Methodology; Hydrogeological Risk Assessment for Land Contamination" can be used. The methodology involves increasingly complex equations to derive remedial targets in soil and groundwater. The remedial target is based on reducing the soil and/or groundwater concentrations at the contamination source to a concentration that does not pose an unacceptable risk to receptors.

Remediation

If the results of the GQRA or DQRA indicate that contaminant concentrations pose a significant, or unacceptable risk to critical receptors, the risk evaluation step which follows is likely to identify a need for remediation. The risk evaluation is based on the results of the risk assessment as well as other considerations, such as cost-benefit considerations.

Account has to be taken of the practicability, durability and effectiveness of remediation options, and whether remediation is reasonable given the likely cost and the seriousness of the harm or pollution. In general, remediation requires assessment, remedial treatment, and monitoring. Remedial activities may require planning permission and/or other environmental permits.

Remediation may involve:

- Contaminant removal, destruction or conversion to less mobile or toxic form;
- Blocking the pathway between the source and receptors;
- Changing the receptor, e.g. from residential to commercial land use.

The degree of remediation required for an area of contaminated land is primarily dependent on its intended use. In practice this means that, for example, a site to be redeveloped as a car park would require less stringent remediation than a site proposed for housing.

Traditional engineering approaches in the UK have included excavation and removal of contaminated soil to licensed landfill and containment/capping in situ.

Remediation treatment technologies can be applied either ex-situ (excavation of soil followed by treatment) or in-situ. Some examples of remedial treatments are outlined below:

Ex-situ bioremediation

Windrow turning (a term borrowed from a composting technique in agriculture) involves the mechanical excavation of contaminated soil and placement into thick layers or heaps. Regular mechanical turning and tilling of the heaps is then carried out to improve the aeration of the soil. Naturally occurring micro-organisms in the soil facilitate biodegradation of the contaminants and thereby reduce the concentrations to a site- specific remedial target. Clearly, this technique is only suitable for biodegradable substances (e.g., petroleum hydrocarbons).

Electro-remediation

This involves the application of an electric current to an array of electrodes embedded in the soil.

Electrolysis, electrophoresis and electro-osmosis induce movement of contaminants in the pore water toward the electrodes. Purging solutions are pumped into the porous electrode housings to remove the contaminants to the surface where they are pumped to a water treatment plant for contaminant removal. This method only works for charged particles; some hydrocarbons will still be present for sites contaminated with these substances.

Chemical Processes

Oxidation/reduction or redox reactions are used to achieve a reduction in toxicity or solubility of contaminants such as organic compounds and heavy metals. Examples include oxidising agents such as ozone, hydrogen peroxide and chlorine gas and reducing agents such as specific iron compounds, sodium and zinc metals, and alkaline polyethylene glycols.

Dechlorination involves the use of reducing agents to remove chlorine atoms from chlorinated compounds to form less hazardous compounds. This process can be used to treat polychlorinated biphenyls (PCBs), organochlorine pesticides and volatile halogen hydrocarbons.

Chemical Extraction involves the extraction of a contaminant using, for example, organic solvents or acids for metal extraction and subsequent treatment of the extraction liquid.

Monitored natural attenuation is also being used as a remedial method in the UK. Natural attenuation reduces the risks posed by contamination in soil and or groundwater using naturally occurring processes.

These include a variety of physical, chemical, or biological processes that, under favourable conditions, act without human intervention to reduce the mass, toxicity, mobility, volume, or concentration of contaminants in soil or groundwater. These in situ processes include biodegradation, dispersion, dilution, sorption, volatilisation and chemical or biological stabilisation, transformation, or destruction of contaminants.

The use of natural attenuation as a remedial method involves the assessment of suitability of the site i.e. proximity of receptors to the site, rate of contaminant migration, toxicity of contaminant and the development of an effective monitoring programme with contingency plan. Engineered solutions may accompany the use of natural attenuation for example impermeable vertical barriers. Successful applications of natural attenuation include the clean-up of chlorinated solvents, pesticides, phenols and some inorganics.

The Role of the Chemist

Contaminated land management requires an integrated approach from a multi-disciplinary team. It should include chemists who understand the behaviour and toxicity of chemicals in the environment, and who are able to evaluate the results of chemical testing based on an understanding of the analytical methods used and the information they provide.

Contaminated land management must also integrate the skills of other professionals including civil and geotechnical engineers, geologists, hydrogeologists, and environmental scientists. The team can combine their skills to provide an understanding of how chemical contaminants are likely to behave in the ground, determine which exposure pathways are likely to be plausible based on the ground conditions and decide which remedial treatments may be effective based on the likely chemical reactivity, availability, toxicity, etc.

Chemists may be involved at various stages of the contaminated land management process. They may be employed as professional advisers or environmental consultants to advise clients on some or all of the stages involved in the investigation, assessment and remediation of contaminated land. They may also work for the regulatory authorities involved in the identification and inspection of contaminated sites.

The chemist may be responsible for generating site specific assessment criteria and remedial targets as part of a DQRA and designing a remedial strategy. This may involve liaison with the regulatory authorities to discuss any specific requirements for the site. As part of the remedial strategy, it may be decided to excavate contaminated soil for off-site disposal to landfill and the chemist may be responsible for carrying out an assessment of any hazardous properties of the waste soil.

Chemists may also be employed by laboratories involved in the analysis of contaminated soils, water and gas samples. Their duties may also include supervision of site investigations to identify and quantify contamination, and the design of future monitoring programmes to assess changes in the site contamination status.

When acting as professional advisers on contaminated land issues, chemists must be wary of pressure to give advice biased towards commercial considerations. For example, property developments may have to be completed quickly allowing little time to investigate the contamination. If contamination has not been adequately characterised and managed, then delays, cost increases and disruption may occur to the development programme. The adviser should discuss potential risk issues, which may have technical, legal and financial implications, with the client. In addition, there are various limitations and unknowns which limit the risk assessment process, and these should be clearly communicated to the client.

There are a number of uncertainties associated with the sampling and analysis of potentially contaminated land. An accredited laboratory should be used to guarantee consistent performance, and quality control procedures should be in place from the time of sampling to the production of analytical results. A sampling programme should be prepared introducing sampling protocols and the sample QC and blank programme. The chosen sampling method and protocols must ensure representative sampling (for risk assessment purposes), and appropriate preservation techniques must be used to prevent loss of contaminants. The analytical methods used must achieve the required limits of detection and the results reported must take into account total uncertainty.

As an example, there are various analytical methods available for determining contaminant concentrations and speciation. The method of analysis must be chosen with care on the basis of knowledge of previous site use and therefore likely contaminant species. Also the choice of analytical method is influenced by the assessment of contamination to be carried out. For example, if the consultant chemist needs to assess the potential human health risks associated with contamination using quantitative risk methodologies, then the relevant chemical species must be quantified.

Conclusions

The UK, along with other industrialised nations, has suffered a legacy of soil and groundwater pollution. Current UK legislation and statutory guidance forms a positive framework for the management of contaminated sites, based on the concepts of risk assessment. The risk-based management of potentially contaminated land through inspection, assessment and remediation is a complex process. Chemists have a vital role to play in all stages of this process, alongside other relevant specialisms.

Further Reading

BS10175:2011. Investigation of potentially contaminated sites – Code of Practice. British Standards Institution, London. 2011. Available from: https://www.britishstandard.org.uk/pub/bs-101752011--investigation-of-potentially-contaminated-sites.-code-of-practice-9780580681981.aspx

Contaminated Land Remediation. Defra Research Project SP1001. Final Report. 2011. Available from: http://randd.defra.gov.uk/

Environmental Protection Act 1990: Part 2A. Contaminated Land Statutory Guidance. Defra, April 2012. Available from: https://www.gov.uk/government/publications/contaminated-land-statutory-guidance

Human health toxicological assessment of contaminants in soil, SC050021/SR2, Environment Agency, August 2008. Available from: https://www.gov.uk/government/publications/human-health-toxicological-assessment-of-contaminants-in-soil

Land contamination risk management (LCRM) webpages, October 2020. Available from: https://www.gov.uk/government/publications/land-contamination-risk-management-lcrm

Remedial Targets Methodology; Hydrogeological Risk Assessment for Land Contamination, Environment Agency, December 2006. Available from: https://www.gov.uk/government/publications/remedial-targets-worksheet-v22a-user-manual

Updated technical background to the CLEA model, SC050021/SR3, Environment Agency, August 2008. Available from: https://www.gov.uk/government/publications/updated-technical-background-to-the-clea-model

Using Soil Guideline Values. Report SC050021/SGV Introduction. Environment Agency, Bristol. 2009. Available from: https://www.gov.uk/government/publications/contaminated-soil-assessing-risks-on-human-health

Relevant organisations

Defra http://www.defra.gov.uk

Scottish Government http://www.scotland.gov.uk

Environment Agency http://www.environment-agency.gov.uk

Natural Resources Wales http://www.naturalresourceswales.gov.uk

Scottish Environment Protection Agency http://www.sepa.org.uk

Northern Ireland Environment Agency http://www.ni-environment.gov.uk/

Society of Brownfield Risk Assessment (SoBRA). https://sobra.org.uk/

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