Environment, Health and Safety Committee Note on:

Contaminated Land

Pre-amble

This Note outlines the regulation of contaminated land, the site investigation and assessment methodology and explains the role of chemists and chemistry in relation to contaminated land. Sources of further information are given for those who require more detailed information.

This Note is designed to provide basic information and advice for RSC members. It may also be useful to others with a particular interest in the subject. It replaces the previous RSC EHSC Note on contaminated land published in 2001.

Introduction

The UK along with other industrialised nations has a legacy of land that is contaminated with materials from previous use. This can result in soil and groundwater pollution with consequent 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 particular emphasis on the important contribution of chemists.

Why is Contaminated Land a Problem?

The UK Government's "brownfields initiative" set a target of 60% of new homes to be built on so called 'brownfield land' i.e. land that has previously been developed. [NB - not all brownfield sites are contaminated or located in urban areas]. The target of almost four million homes which projections suggest will be required in the UK by 2016 will inevitably lead to a demand for redevelopment of land that is currently contaminated. Further, the Government's proposals for urban renaissance require that brownfield sites be prioritised for development in advance of greenfield sites.

The Environment Agency's "State of the Environment Report for Land" (2000) indicates that 33,000 hectares of developed land lie vacant or derelict in the UK. 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 II(a) of the Environmental Protection Act 1990

Part II(a) defines contaminated land in terms of risk assessment. The Act provides the current statutory framework for dealing with contaminated land in the UK and was introduced under Section 57 of the Environment Act 1995 and came into effect in England and Scotland in 2000 and Wales in 2001. The regime is based on the identification and remediation of contaminated land and gives a statutory definition based on the risks of significant harm to

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Version 2: 28 July 2009

specified receptors or 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) pollution of controlled waters is being, or is likely to be, caused*".

Part II(a) was extended in 2006 to include radioactivity in England and Wales but this currently only applies to human exposure to radioactivity.

Local Authorities are responsible for the inspection of contaminated land and for ensuring remediation is undertaken where necessary. Local Authorities 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.

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 considered to be potentially contaminated, the local planning authority will take this into account and may require investigative work to be completed by the applicant.

Developers (applicants) often commission specialist environmental consultants to conduct contaminated land investigations on their behalf. The resulting assessment of these investigations can then be submitted with the planning application to the Local Authority for approval that the site is suitable for the proposed use.

Planning permission may be granted on condition that the site is remediated to the satisfaction of the Local Authority depending on the results of any investigation. New planning guidance (PPS23) was launched in November 2004, and this includes an Annex 2 which gives more detailed guidance about development on land affected by contamination.

The main difference between Part II(a) and PPS23 is that under the planning system, risks have to be assessed based upon the new or intended use of the land, rather than on the existing use, which was a criterion in the Part II(a) regime. For more information on the regulation of contaminated land, refer to Defra Circular 01/2006 and Planning Policy Statement 23 [See Annex 1].

The Environment Agency will provide advice to Local Authorities on remediation of contaminated sites, and on identifying and dealing with pollution of controlled waters.

Source-Pathway-Receptor Linkages

The current contaminated land regime in England advocates a risk-based approach to the management of contaminated sites. Risk assessment incorporates an assessment of contaminant-pathway-receptor relationships [see Annex 2] to restore sites 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.

A key tool in the investigation and assessment of potentially contaminated land is deriving and updating a conceptual model through various phases of work. A risk assessment of the source-pathway-receptor linkages identified in the conceptual model can then be performed.

Investigation

Typically environmental consultants are employed to investigate contaminated land sites and this may be on behalf of a developer (applicant) whom is seeking to be allocated planning permission for development of a brownfield site or the consultant may be working on behalf of the Local Authority assisting with the Part II(a) inspection strategy of that authority. Investigations typically involve several phases of work with the final phase being remediation and validation if significant risk from contamination is identified.

A Phase I (Desk Study) involves the identification of potential sources of contamination, pathways and receptors by assessment of desk based information such as historical plans, geological maps and industrial profiles. A qualitative risk assessment is then performed for the site based on the conceptual model.

Where the Phase I Desk Study identifies potentially significant source-pathway-receptor linkages, then a Phase II (Site Investigation) may be carried out to provide quantitative information on the contaminant source, to assess pathways and the risk to the receptors as part of a Generic Quantitative Risk Assessment (GQRA). Phase II involves obtaining soil and/or groundwater samples and submitting them for chemical analysis. Soil and rock samples are obtained by the drilling or excavation of the ground.

Contaminant concentrations in soil and groundwater are compared with available generic assessment criteria and if concentrations are particularly elevated, then a Detailed Quantitative Risk Assessment (DQRA) can be performed. A DQRA involves the use of computer models to derive Site Specific Assessment Criteria (SSAC) for comparison with contaminant concentrations in soil.

Human Health Risk Assessment

As part of a GQRA, Generic Assessment Criteria (GAC) are used to compare against contaminant concentrations in soil. Soil Guideline Values (SGVs) are a type of GAC published by DEFRA/Environment Agency. SGVs represent "trigger values", indicators to a risk assessor that above this level, soil concentrations may pose a possibility of significant harm to human health.

These values are derived for various generic land uses (residential, commercial) using the Contaminated Land Exposure and Assessment (CLEA) model based on generic assumptions which was originally issued in 2002 and has been subsequently revised with the latest version detailed in Environment Agency document SC050021/SR3. The original published SGVs (pre-2008) were removed by the Environment Agency in August 2008.

The Environment Agency are issuing new SGVs on a rolling programme from March 2009 and risk assessors are able to derive their own GAC values using the CLEA model software package as detailed in Environment Agency (EA) document SC050021/SR4.

SGVs published between March and July 2009 includes BTEX, arsenic, mercury, nickel and selenium. Land Quality Management (LQM) and the Chartered Institute of Environmental Health (CIEH) published their updated GAC values in July 2009. A group of volunteers from a range of environmental consultancies working with the Contaminated Land: Applications in Real Environments (CL:AIRE) and the Environmental Industries Commission (EIC) have also been working on a range of contaminants throughout 2009 with the intention to publish GAC values in Autumn 2009.

Both the LQM/CIEH and EIC/CLAIRE based GAC projects have aimed to compliment the EA SGV programme by deriving GAC for substances where the EA has not yet published values or they are not considering deriving SGVs in the short to medium term.

The CLEA model software can also be used by risk assessors to derive SSAC values as part of a DQRA to compare with contaminant concentrations in soil. The CLEA model is limited in the number of pathways considered and can only be used to assess the risk to long term human health from contaminants in soil.

Groundwater Risk Assessment

The Environment Agency published the Remedial Targets Methodology; Hydrogeological Risk Assessment for Land Contamination in December 2006 which provides a tiered structure for assessing the risk to groundwater and surface water receptors from soil and/or groundwater contamination. The methodology involves increasingly complex equations to derive remedial targets in soil from Level 1 to Level 4 and in groundwater from Level 2 to 4. The remedial target becomes less conservative at increasing levels as more site specific data is used. The remedial target is based on reducing the soil and/or groundwater concentrations at the contamination source to concentration that poses no significant risk to receptors.

Remediation

Remediation is usually required when the results of the GQRA or DQRA indicate that contaminant concentrations pose a significant risk to critical receptors.

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 source removal, destruction or conversion to less mobile or toxic forms;
- 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 dependant on its intended use. In practice this means that 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 TPH-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 petroleum hydrocarbons and thereby reduce the source concentrations to a site specific remedial target.

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 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.

Natural monitored attenuation is also being used as a remedial method by some large chemical companies in the UK. Natural attenuation reduces the risks posed by contamination in soil and or groundwater using naturally occurring processes.

The natural attenuation processes that are at work in such a remediation approach 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 have an understanding of the behaviour and toxicity of chemicals in the environment, and who are able to evaluate the results of chemical testing analyses 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 on the basis of 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.

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 undertake a variety of other roles. For example, chemists working for the regulatory authorities may be involved in the identification and inspection of contaminated sites. They may 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 sampling and analysis of 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, 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 chemical species must be quantified by the analytical method. For example testing for total volatile organic compounds would not provide the necessary speciation for the risk assessment input parameters.

Conclusions

The management of contaminated land through inspection, assessment and remediation is a complex issue. Chemists have a vital role to play though an effective approach to contaminated land requires input from a range of specialisms.

The UK along with other industrialised nations has suffered a legacy of soil and groundwater pollution. Current UK legislation and statutory guidance on contaminated land forms a positive framework for the management of contaminated sites based on the concept of risk assessment. The potential for contamination to have an adverse effect on human health and the environment forms the basis of the decision making process for management of contaminated sites.

Sources of further information.

Environment Agency ‘The State of the Environment of England and Wales: The Land’, Environment Agency, 2000, ISBN 0-11-3101-66X;

British Standard Code of Practice, “Investigation of potentially contaminated sites”, BSI London 2001;

Defra Circular 01/2006, Environmental Protection Act 1990: Part 2A Contaminated Land, September 2006;

Remedial Targets Methodology; Hydrogeological Risk Assessment for Land Contamination, Environment Agency, December 2006;

Model Procedures for the Management of Land Contamination, Contaminated Land Report 11, Environment Agency, September 2004;

Human health toxicological assessment of contaminants in soil, SC050021/SR2, Environment Agency, August 2008;

Updated technical background to the CLEA model, SC050021/SR3, Environment Agency, August 2008;

CLEA Software (Version 1.03 beta) Handbook, SC050021/SR4, Environment Agency, August 2008;

"Remedial Treatment for Contaminated Land", (Twelve Volumes), CIRIA Special Publications 101-112, (Harris, M.R., Herbert, S.M. and Smith, M.A.) CIRIA (London), (various dates).

Annex 1 – Relevant Organisations

Environment Agency
www.environment-agency.gov.uk

Scottish Environment Protection Agency
www.sepa.org.uk

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

SILC, Specialist in Land Condition
www.silc.org.uk

CLAIRE – Contaminated Land: Applications in Real Environments
www.claire.org.uk

Annex 2 – Definitions of Contaminated Land

In the UK contaminated land is defined in the Environment Act 1995 as "any land which appears to the local authority in whose area it is situated to be in such a condition, by reason of substances in, on or under the land, that (a) significant harm is being caused or there is a significant possibility of such harm being caused, or (b) pollution of controlled waters is being, or is likely to be, caused".

This definition of contaminated land is intended to embody the concept of risk assessment. Determination that there is a significant possibility of significant harm being caused should be made in accordance with the guidance by carrying out a site specific risk assessment. In the guidance risk is defined as the combination of the probability of frequency of occurrence of a defined hazard and the magnitude of the consequences.

A significant contaminant - pathway (by which the contaminant may reach the receptor) - receptor (of contamination) relationship must exist for the land to be identified as contaminated. The need for remedial action can be determined by assessing contaminant-pathway-receptor (CPR) relationships (pollutant linkages) to consider the potential for significant harm to receptors e.g. human health, ecosystems, livestock, crops and buildings/property. Pollution of controlled waters constitutes a further type of pollutant linkage under the new regime. In addition, Section 161 of the Water Resources Act 1991 details the statutory liability for clean up of water pollution. There is a requirement under the new Environmental Permitting regime to identify information on the baseline conditions in respect of contaminated land as part of the application process.

Some definitions of contaminated land have been used in the past which remain useful in practice. For example, the British Standards Institution in 1983 defined contaminated land as land that contains any substance that when present in sufficient concentration or amount presents a hazard. The hazard may:

(a) be associated with the present status of the land
(b) limit the future use of the land
(c) require the land to be specially treated before particular use.

Cairney's definition in 1987; "Land that contains substances that when present in sufficient quantities or concentration are likely to cause harm, directly or indirectly to man, the environment, and on occasions other targets" is also useful.

RSC Environment, Health and Safety Committee (EHSC) gratefully acknowledges the assistance and input of Mr J Lymer in revising the latest version of this Note.

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