Urban Regeneration Of Coalfields: Generic Studies of Contaminated Land and Groundwater Issues Exemplified in Wolverhampton

Objectives

The impact of contaminated land on the urban environment is strongly controlled by the nature (speciation) of contaminants present and the potential of these to migrate to ground and surface water. This project is addressing the following interrelated themes centred around the Wolverhampton conurbation:

- groundwater and contaminant transport modelling
- speciation studies and speciation modelling
- contaminant mobility studies.

These three tasks will lead to an improved generic basis for contaminated land risk assessment. The project benefits from current Environment Agency sampling activity and groundwater data, as well as the recently completed British Geological Survey 'Wolgis' hydrogeological and geological database.

Location

West Midlands

Approach

Groundwater and contaminant transport modelling:

- to define current water levels in the area and predict future rises dependent on a number of future development scenarios
- to describe and predict the effect of rising water levels and land use changes on groundwater quality, particularly the consequences of saturating waste and contaminated land previously above the water table.

Speciation studies and speciation modelling:

- to determine the concentration of Potentially Harmful Elements (PHEs) in the different size and mineralogical fractions of the contaminated solid material
- to directly determine the aqueous phase chemical speciation of PHEs (redox states, inorganic/organic complexes) in leachates, extracts, porewaters and groundwaters derived from the solid material (in conjunction with the contaminant mobility studies)
- to predict aqueous phase PHE speciation by geochemical modelling.

Contaminant mobility studies:

- to establish the leaching behaviour of contaminated soils exposed to various groundwaters likely to be encountered in urban areas
- to provide leached aqueous samples for specification studies, the results of which will help validate speciation modelling
- to compare the total and species concentrations of PHEs, their relative mobilities and significance to overall site risk assessment

- to assess several laboratory test methods for investigating leachability and to develop guidance on the interpretation of such tests in the context of speciation and on the use of speciation models.

Deliverables

Groundwater and contaminant transport modelling

In addition to a contaminant transport model for the Wolverhampton conurbation, which can be further developed as data becomes available or used to guide development, this activity will deliver:

- maps illustrating the current and future groundwater configurations and surface water flows resulting from a range of possible future scenarios
- maps showing areas where contaminants may be mobilised as a result of rising groundwater or change in land use
- maps predicting future contaminant concentrations at sensitive points of water use.

Speciation studies and speciation modelling

This activity will deliver:

- new datasets to compliment existing total element concentrations databases and give new insights into the occurrence, mobility, fate and transport of PHEs in the environment
- new protocols for rapid screening of PHEs in contaminated soils and groundwaters
- validation of speciation predictions
- an improved groundwater flow and geochemical speciation model to support contaminated land risk assessment.

Contaminant mobility studies

Deliverables from this activity are:

- source term leaching for a range of contaminated land types in terms of total PHE concentrations and species concentrations
- guidance documentation on leaching test methods.

Start date/duration

January 1998 Four years

Lead Organisations

University of Sheffield
Macaulay Land Use Research Institute
British Geological Survey

Users

Environment Agency
Sheffield City Council
Wolverhampton Metropolitan Borough Council
Glasgow City Council

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Integrated Assessment And Modelling Of Soil Contaminant Behaviour, Transport and Impact At Remediable Urban Sites

Objectives

This project is focusing on key urban sites which have been impacted by inorganic and organic contaminants to provide an integrated assessment (including linked chemical and physical modelling) of:

- how indigenous physicochemical conditions at such sites, together with a perturbation in any particular characteristic, especially a change in pH, redox or influx of organic matter, influence contaminant behaviour
- the implications of this for the selection of an appropriate remedial technique
- how, in a post-remedial scenario, residual concentrations of the contaminant, or remediation 'products', and biological activity will also be influenced by physicochemical conditions and their perturbation.

To address these issues, two key groups of contaminated land in Central Scotland have been selected:

- sites impacted by hexavalent chromium in south-east Glasgow (Rutherglen and Cambuslang)
- sites impacted by polycyclic aromatic hydrocarbons in the Glasgow/Motherwell conurbation.

Location

"Greater" Glasgow

Approach

Heavy metal contaminated sites

A new modelling framework, developed by Dr Meeussen at Macaulay Land Use Research Institute, is being applied to the sites around Glasgow which have been heavily contaminated with chromium-containing wastes. This approach uses a new algorithm which simplifies the matrix algebra involved while the chemical reactions and physical processes responsible for the behaviour of the metal contaminants are 'modelled' in the form of equations which interact with the central core when required. Alongside this, conventional analytical techniques and methods of solid state characterisation are being used to provide inputs for the modelling.

Polycyclic aromatic hydrocarbon contaminated sites

Soil samples from the fuel-oil (and past carbonisation-process) contaminated site near Motherwell are being subjected to a range of extraction procedures, including supercritical fluid extraction and accelerated solvent extraction. The subsequent use of GC-MS and GC-C-IRMS enables identification, quantification and source apportionment of PAHs to be achieved. In addition, the factors influencing the behaviour and degradation of PAHs in soils are being investigated.

Assessment of biological activity prior to and post-remediation

Microbiological activity is being investigated in soils at both types of contaminated site. For the
Cr-contaminated sites, single species microbial bioassays are being used to establish the toxicity of both Cr(III) and Cr(VI) such that they may be used to establish end points for remedial treatments.

Start date and duration

March 1998 January 2002

Lead Organisations

University of Edinburgh
Macaulay Land Use Research Institute
East of Scotland Water Authority
Scottish Universities Research and Reactor Centre
Dames and Moore

Deliverables

This project will aim to bring the following benefits to the user community:

- an understanding of how particular soil conditions may determine (a) the likely durability of a particular remedial technique where there may be future changes in soil physicochemical properties, and (b) the effectiveness of particular remedial technologies in achieving specific remedial goals through their influence on contaminant behaviour - this knowledge will be transferred to the user community through the development of a specific computer-based model for the behaviour of Cr-contaminated sites
- an understanding of the extent to which biological activity in remediated soil can be restored through a manipulation of physicochemical properties.

This information will facilitate decision makers in their selection of remedial technologies and provide an important tool for assessing the cost-effectiveness of technological inputs in the remedial scheme.

Users

Glasgow City Council
Scottish Environment Protection Agency
South Lanarkshire Council

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In-Situ Sensing of the Effect of Remediation on Available Metal Fluxes in Contaminated Land

Objectives

- to develop multi-element, in-situ diffusive gradients in thin-films (DGT) probes for measuring metal re-supply fluxes in urban soils and to verify their use for Cd, Co, Cr(III), Cu, Fe, Mn, Ni, Pb and Zn
- to use the re-supply fluxes to calculate hazard factors
- to assess how hazard factors relate to physicochemical soil characteristics and to soil microbial activity
- to investigate the effect of remediation on hazard factors
- to assess small-scale variability in metal re-supply.

Location

Generic

Approach

DGT offers great potential as a simple diagnostic tool for assessing the risk posed by contaminated land, but it still requires careful testing. This project will use DGT to perform measurements on the two key groups of contaminated land in Central Scotland that are the subject of an URGENT Programme first call project entitled *Integrated Assessment and Modelling of Contaminant Behaviour, Transport and Impact at Remediable Urban Sites*. It will exploit the information available to further the understanding of DGT measurement in real conditions. The work will be fully integrated into the existing project, for which it will provide complementary information on the kinetics of metal re-supply and potential availability.

Start date/duration

October 1998 Three years

Lead Organisation

Lancaster University

Deliverables

This project will ultimately lead to:

- establishment of a new procedure for quantitatively assessing the potential hazardous nature of soils
- the development of an in-situ test probe
- a procedure for examining microniche mobilisation of metals
- assessment of how remediation procedures affect available metals.

Although focused on a series of specific sites in Central Scotland, the outcome and benefits of the project will be generic.

Users

Academic institutions
Environmental regulators and enforcement agents, both national and regional
Industrial companies
Consultants

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Non-Invasive Characterisation of NAPL-Contaminated Land by Spectral Induced Polarisation (SIP) Tomography

Objectives

The main aims of this project are to:

- research the complex geoelectric properties, in the frequency bandwidth mHz to kHz, of Triassic sandstone aquifer rocks contaminated by common industrial Non-Aqueous Phase Liquids (NAPLs), eg chlorinated solvents, hydrocarbons, coal-tars
- study SIP images obtained from controlled release NAPL experiments in a medium-scale laboratory sand tank to provide a physical insight on NAPL behaviour in porous and fractured media
- develop and test new 2.5D mathematical algorithms for the robust inversion and reconstruction of SIP images for the full SIP frequency range
- undertake field trials at well characterised industrial sites to check SIP spectra, laboratory results and imaging code against known contaminant models and ground-truth.

Location

West Midlands

Approach

The project comprises five main work packages, each of which is subdivided into specific tasks as follows:

Work package 1: Laboratory characterisation of NAPL-contaminated and clean samples to relate SIP phase spectra to known chemical, mineralogical and pore-fluid properties
Task 1: Petrophysical and mineralogical characterisation.
Task 2: Chemical analysis of contaminated samples.
Task 3: Measurement of the SIP spectra of the samples.
Work package 2: Model tank/column experiments using controlled releases of NAPLs to correlate SIP spectra and images against known geometries, media properties, flow-paths and hydraulic parameters
Task 4: Controlled release of NAPLs.
Work package 3: Development and testing of 2.5D numerical inversion software
Task 5: Development of 2.5D forward modelling scheme for full SIP frequency bandwidth.
Task 6: Development of 2.5D inversion software.
Work package 4: Field trials at industrial sites to validate laboratory and interpretive criteria
Task 7: Trial surveys undertaken in the West Midlands conurbations, much of which are underlain by Triassic sandstone.
Work package 5: Project management
Task 8: Overall co-ordination of the principal research tasks, reports, maintaining schedules, budget control, QA and liaison with EPSRC by the British Geological Survey.

Start date/duration

April 1999 Three years

Lead Organisations

British Geological Survey
University of Birmingham

Deliverables

This project will develop SIP as a cost-effective, non-invasive geophysical scanning technique to map and monitor organic contaminant distributions. In addition, 2.5D code will be developed to cover the full SIP frequency range (mHz to kHz).

Users

Environment Agency
Chemical and construction industries
Water companies
Planning and regulatory authorities
Land re-developers
Insurance or financial houses for risk assessment
Health and Safety authorities

Further Details

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The Use of Computational Chemistry to Investigate the Behaviour of PAHs in Sediments

Objectives

Polycyclic aromatic hydrocarbons (PAHs) are widespread in urban soils and made ground. As carcinogens they are a major environmental concern. Although readily partitioned from the water phase into the soil matrix, once incorporated PAHs are difficult to remove. Characterisation of the interaction of PAHs with the soil matrix and importantly with the organic fraction (humic material) is needed in order to understand the long-term behaviour, improve analytical quantification and develop effective remediation strategies for PAHs. The project aims to:

- provide support to the URGENT Project by the development and application of methods to establish feasable molecular structures and conformations of humic compounds suitable for incorporation into computational models
- translate the molecular information into models of PAH adsorption/desorption behaviour in the soil matrix

Location

Generic

Approach

The project will examine the molecular dynamics of organic and inorganic compounds by computational chemical techniques already established in many fields of chemical research. The use of computational techniques allows the study of the molecular dynamics of adsorption, phase partitioning and submicroscopic aggregation of molecules in exactly defined organic/inorganic systems. This will help to reveal the processes responsible for the complex desorption behaviour of PAHs.

This project will be allied to the URGENT Project, Integrated assessment and modelling of soil contaminant behaviour, transport and impact at remediable urban sites, and will allow incorporation of the findings from that study into computationally and chemically realistic models of the soil organic fraction.

Start date/duration

July 1999 9 months (feasibility)

Lead Organisation

University of Newcastle upon Tyne

Deliverables

- The linkage of this and the allied soil contaminants project will provide information useful for the development of new soil remediation techniques.
- Developments of molecular modelling techniques should be of benefit to the future design of surfactants for the removal of organic pollutants from contaminated sites

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Studies Into Metal Speciation and Bioavailability to Assist Risk Assessment and Remediation of Brownfield Sites in Urban Areas

Objectives

- To improve and optimise methodologies for the source apportionment for potentially toxic elements and species in urban soils, especially in brownfield locations.
- To determine the relative inputs and dispersion patterns arising from different sources of contamination, such as industry, domestic use and transport systems in relation to the natural background.
- Using chemical and mineral speciation techniques, to determine relative metal mobility and bioavailability in the soil profile.
- To apply a novel technique, based on microporous polymer samplers, to establish metal concentrations in soil solutions as a further measure of potential bioavailability.
- To develop methods for predicting free soil solution metal concentration (M^{2+}) from existing spatially-coordinated soil metal datasets (M_{soil}) and to assess the value of this secondary information in the development of land remediation priorities.
- To test, by 'ground truth' measurements of metal concentrations in soil solutions and plant uptake, the validity of a range of partly-mechanistic metal solubility and plant transfer algorithms in urban soils.
- To apply the results of items 2-6 to improve the assessment of fluxes, pathways and sinks of lead and associated potentially toxic elements and species related to land use characteristics, exposure and risk.

Location

West Midlands

Approach

The project will comprise the following interlinked modules:

Module 1: site locations and bulk geographical data (months 1-6)
Module 2: solubility and bioavailability of elements (months 6-14)
Module 3: predicting metal ion concentration in the soil solution (months 4-12 and 16-29)
Module 4: soil to plant metal transfer factors (months 5-12 and 16-24)
Module 5: application of Pb and other metal high precision isotopic measurements (months 7-27)
Module 6: chemical and mineral forms (months 7-24)
Module 7: risk assessment (months 25-30)
Module 8: decision support system for diagnosis of metal contamination (months 25-30)

Start date/duration

October 1998 Two years and six months

Lead Organisations

Imperial College London
University of Nottingham
University of Leicester

Deliverables

This project will (a) prepare GIS maps for informed decision making on environmental issues related to lead contamination and (b) provide, through consultation with the user community, a decision support system to quantify the risk from contamination, in particular, for the development of urban brownfield sites.

Users

Local Authorities
Environment Agency
Department of the Environment, Transport and the Regions

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Environmental Information Systems For Sustainable Urban Planning, Regeneration and Management

Objectives

This research will deliver information systems and decision aids for use by planners, developers and other stakeholders involved in urban regeneration. The project will:

- identify and prioritise user requirements and issues in the selected sector(s)
- develop structured approaches to address these requirements and, through a decision-rule base, to incorporate these into a prototype decision-aid system
- identify the key information sets which are required at various stages of the decision-making process and to assemble these from existing sources
- load data into the prototype decision-aid system and to test the system with trial questions from the user community at both strategic (regional, sub-regional) and specific (neighbourhood, site) level
- disseminate information through the internet, publications, a digital demonstration package and seminar/workshops for interested organisations

Location

Generic

Approach

- Use of a scoping study to guide the research
- Assembly of data, analytical tools and models from a wide range of areas of environmental concern
- Development of generic framework for integrating analysing and reporting environmental information
- Provision of a structured approach to urban management using Spatial Decision Support Systems Provision of expert systems to assist in managing key issues at a local and strategic level

Start date/duration

October 2000 Three years

Lead Organisations

British Geological Survey, Keyworth
University of Nottingham
CEH Wallingford
CEH Monks wood
CEH Bush

Deliverables

- A series of realistic case studies (additional help system and user notes)
- On-screen aids to guide users
- A full report of methods and findings
- A demonstration decision aid system and associated training package, distributed on CD. Key information will be made available on the WWW

Users

DETR
English Heritage, English Partnerships
Telford and Wrekin
Glasgow City and Newham Councils and others

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Detection of Abandoned Mineshafts and Mine-Waste by Capacitively-Coupled Resistivity Imaging (CCRI)

Objectives

- To design and develop a towed capacitively-coupled resistivity imaging (CCRI) system for the 3D imaging of buried mineshafts and waste-products in the built environment.
- To integrate modern Real-Time Kinematic Global Positioning Systems (RTKGPS) with the resistivity measurements to accelerate data-capture and accurate positioning in real-time.
- To apply 2D/3D imaging schemes (Occam inversion) to improve image reconstruction, target resolution and recognition.
- Undertake field trials at well-characterised ex-mining sites to assess performance of CCRI, RTKGP and imaging software against ground-truth.
- Disseminate the results via publications, conferences. Prepare a Technology Implementation Plan to cover exploitation of any derived technology, software or results.

Location

Midlands

Approach

The project will comprise 5 main workpackages:

Workpackage 1: Instrumental design and development of capacitive electrode arrays.

Workpackage 2: Develop interfacing software to link a commercial RTKGPS positioning system to the CCRI unit to allow towed or random surveying.

Workpackage 3: Adapt Finite-Element modelling code for 2D/3D inversion of CCRI survey data and tomographic image reconstruction.

Workpackage 4: Field experiments at selected test sites in the West Midlands to calibrate the CCRI measurements against ground-truth.

Workpackage 5: Project Management.

Start date/duration

October 1999 Three years

Lead Organisation

University of Nottingham

Deliverables

The proposed system aims to improve the detectability of physical and environmental hazards associated with abandoned mines and to minimise the cost of intrusive sampling in highly heterogeneous ground conditions. The principal beneficiaries, therefore, will be the construction and engineering industries, planning authorities and environmental protection agencies. Contaminated and unstable ground is not just a threat to health and safety but also has a blighting influence on property values, planning and economic re-generation. Rapid, high-density scanning of the shallow surface will improve confidence that the land is fit for purpose and arbitrary protection zones could be reduced accordingly.

Users

Scott Wilson Kirkpatrick & Co Ltd
Geometrics
Wardell Armstrong
Mine Investigation & Stabilisation Ltd
The Coal Authority

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Response of Archaeological Sediments and Artefacts to Imposed Stress Regimes as a Consequence of Past Present and Future Anthropogenic Activity

Objectives

This project will link field archaeological site investigation with advanced laboratory techniques and theoretical models in soil mechanics, to examine how the stresses imposed as a consequence of loading and consolidation in urban environments affect the in *situ* preservation of archaeological remains. The work aims to:

- Identify important locations for archaeological site preservation within Greater London where detailed work is in progress to establish recent site palaeo-history and associated stratigraphic architecture
- Collect data and samples from sites with a good chronological and stratigraphic record.
- Test site samples in the laboratory to generate the required geotechnical information, collect associated field data to quantify past consequences of overburden for a range of materials.
- Use the data collected to quantify the future consequences of loading by construction activity for a range on anthropogenic and natural earth materials.
- Synthesise field and laboratory data, and carry out laboratory testing on extracted artefacts
- Determine the stress regime on artefacts by analysis of laboratory results, and provide quantitative information for the future preservation of remains at key sites.
- Develop and disseminate recommendations relating site development strategies to potential impact on archaeological heritage in support of Government guideline PPG16.

Location

Greater London

Approach

Existing sites will be identified in collaboration with Museum of London archaeologists, W.S. Atkins consultants and English Heritage. Detailed archaeological characteristics and a three dimensional stratigraphy will be established for each site. Samples will be collected from sections representative of the sedimentary materials present at each site and the physical properties of each of the materials sampled will be established. The consolidation and volume change characteristics will be established for each sediment. Sites will then be revisited and samples with in situ artefacts collected for stress testing. The artefacts will be submitted to laboratory measured loading and relaxation regimes to establish the consequences of varying stress regimes through time.

Start date/duration

October 1999 - Three Years

Lead Organisations

University of Durham
Museum of London

Deliverables

- Provision of a data set and information on the effects of various site-related loading scenarios on in situ artefacts that will be of use to planning authorities, consultancy companies, civil engineers and developers.
- Provision of a rigorous and quantifiable framework for future excavations, complementing and supporting PPG16(DoE, 1990) in identifying criteria for the preservation in situ of archaeological remains.

Users

DoE
English Nature

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Stable Isotopic Characterisation of Extent of Anaerobic Bacterial Dehalogenation of Chlorinated Solvents: A Feasibility Study

Objectives

The main objective of this feasibility study was to determine if bacterial reductive dehalogenation of chlorinated solvents produces a characteristic chlorine stable isotope composition, indicative of the extent of degradation. To confirm this, it was necessary to:

- establish if the isotopic composition, if produced, is independent of the rate of degradation
- confirm that chlorine isotopic composition of solvents is unaffected by contact with aqueous chloride.

Approach

Laboratory degradation experiments
The progress of dehalogenation was monitored and a pilot experiment performed to compare the effects of successive samplings from the same vessel and running replicate experiments for different periods of time. Two sets of controls will be run, without bacteria and with autoclaved bacteria.

Isotopic validity check
This tested for isotopic exchange between phases, which, as expected, was negligible.

Sample analysis
All samples from the laboratory experiments and the field were analysed in the same way. Organic phases were analysed by gas chromatography, which was used as a preparative step for isotopic analysis. Chloride in water was measured by ion-chromatography.

Isotopic analysis
Solvent samples used in the degradation experiments and separated, extracted organic phases were prepared for isotopic analysis using a newly developed method.

Interpretation
The effect for δ^{37}CI was calibrated for the various laboratory experiments. The results were also related to other variables: reaction rate, microbial species and growth conditions.

Summary of principal achievements of the work

i) Scientific achievements (and beneficiaries)
First measurement of chlorine isotope fractionation factor for anaerobic dechlorination (Contaminated land problem holders, Other researchers)
Demonstrated that the isotopic effect is similar for different organisms and that it is sufficiently regular to conform to a Rayleigh Distillation fractionation model (Other researchers)
ii) Practical (and beneficiaries)
Demonstrated feasibility of a robust approach to quantify extent (and thus rate) of microbial degradation of CAH (Those owning, seeking to develop or responsible for regulating, contaminated land: e.g. Industrial companies, National Government [e.g.MoD], Local authorities.

Start date/duration

June 1998 Eight months

Lead Organisation

University of Reading

Deliverables

The hypothesis has been proven in this study, the next stage will be to develop the methods in collaboration with problem holders and other academic researchers.

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