# New developments in groundwater and soil remediation technologies and the challenges facing their application and uptake

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## Introduction to CL:AIRE

• Independent not-for-profit organisation set up by Govt and industry in 1999

• Objectives include:

- to stimulate the regeneration of contaminated land in the UK by raising awareness of, and confidence in, practical and sustainable **remediation technologies** and effective **methods for monitoring and investigating** sites.

-to disseminate technology demonstrations and research





## Setting the Scene

• Over the last 12 years CL:AIRE has seen a major shift change in the use of remediation technologies and those that were being put forward as demonstration projects.

- *Exsitu* technologies which are now considered main stream
- To greater focus of *insitu* technologies where we have seen the greatest innovation and new developments occurring and is main focus of this presentation

• This is confirmed by the recently published Defra Report 2010 – Contaminated Land Remediation Report

## Setting the Scene

Percentage usage of *exsitu* and *insitu* remediation techniques reported in industry surveys between 2005 – 2009

Increases in:

*Insitu* chemical technologies eg. addition of chemicals/oxidation/reaction : 7.5 - 17%

*Insitu* airsparging/venting :15 – 30.1%

Thermal treatments eg. Steam, radiofrequency, electrical conductive heating : 0 – 8.5%

All other technologies used there has been no increase use or have decreased in use.





## *Insitu* Thermal Treatments

*Insitu* thermal treatment involves increasing the temperature in the ground which leads to enhanced contaminant removal. By using electrical energy or radiation it enhances the mobility of organic contaminants in both the saturated and unsaturated zones which can facilitate their recovery and treatment more effectively. Always used in conjunction with a recovery and treatment operation such as soil vapour extraction.

There are four main methods of *insitu heating:*

- *Injection : steam or hot air*
- *Electrical resistance heating*
- *Electromagnetic heating (radiofrequency* or microwaves)*
- *Thermal conductive heating**

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## TDP24 Case Study

**Application of thermally enhanced soil vapour extraction to remediate the unsaturated zone at the Western Storage Area, Harwell (Provectus Group and RSRL)**

**Background**

•Until 1930s: Racehorse stables

•1935 to 1946: RAF airfield

•Nuclear R&D site for over 40 years

•Since mid-1990s, focus on decommissioning and clean up for redevelopment ("Harwell Science and Innovation Campus")

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## TDP24 Case Study

**Western Storage Area (WSA)**

- 25 shallow pits (4-5 m) used for disposal of chlorinated solvents (approx 20 tonnes) and other chemicals
- Pits were excavated and contents removed in 2004
- Residual suite of VOCs & hydrocarbons in unsaturated zone of Chalk up to c25 mbgl

**Project Objectives**

- Target contaminants, reduce loading significantly & minimise emissions
- Undertake pilot trial - design & configure remediation evaluating multiple techniques
- Undertake phased remediation as NDA funding becomes available

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## TDP24 Case Study

**Pilot Trial**

•Site characterisation to gain current data on unsaturated zone contamination profile

•Test SVE technology application

•Examine:

–Conventional SVE

–Targeted depths

–Assistance of air/ozone sparging

–Thermal enhancement

**Recommendations**

Recommended that full-scale remediation of the unsaturated zone is undertaken within the WSA comprising:

•SVE in the vicinity of the former chemical waste disposal pits.

•Thermal enhancement of the SVE in areas of gross contamination.

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## TDP24 Case Study

**Methodology**

•Conductive heating and vacuum extraction applied simultaneously to the impacted zone

•Heater contains an electrically powered heating element with an operating temperature of 500-800ºC

•Heat transfer by thermal conduction can give rise to target zone heating between 100-350ºC

•Contaminants are partitioned into the vapour phase. Vapours are collected continuously using centrally located SVE

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## TDP24 Case Study

**Results and Conclusions**

Extraction Rates:

–At start of un-enhanced trial - 3kg/day

–During Phase 1 thermal enhancement – 17kg/day

–End of Phase 2 enhancement - 3kg/day

–During Phase 3 enhancement - 2kg/day

–Following Phase 3 enhancement - 0.3kg/day

•No free product in nearby groundwater monitoring wells

•VOC and SVOC concentrations in condensate are two orders of magnitude lower following TESVE

•Estimate of total mass of contaminants removed from WSA unsaturated zone currently stands at approximately 1 tonne

Final TDP24 Report is available from CL:AIRE website.

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## TDP28 Case Study

Ecologia undertaking a thermal treatment using radiofrequency technology at a former petroleum site.

•Radio-frequency waves emit heat through antennae within the treatment zone.

•Increases molecular motion which heats the soil.

•Radio-frequency waves have lower energy than microwave energy but has greater penetration and can also heat dry soils.

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# Principle of the RF Technology

Electromagnetic field emitted into the soil

↓

Polar Molecules excited by the electromagnetic field

↓

Heat generated

↓

Increase rate of volatilisation

↓

Reduction in time required for SVE



# Field Trial

## Conclusions

ISRFH technology reduces:

•Time required for remediation by 700% (i.e.7 fold 46 days vs. 325 day)

•Energy input by 42% when compared to a traditional SVE with no heating.

•Energy efficient as heat the soil for 2-3 weeks and as soil is a good insulator it stays warm.

• Final TDP28 report is available from CL:AIRE website.

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## STAR Technology

STAR: Self-sustaining Treatment for Active Remediation

Patent-pending technology based on principles of smoldering combustion

Exothermic reaction converting carbon compounds ➡ $CO_2$ + $H_2O$

Addresses recalcitrant contaminants

Reduced costs versus other technologies

Uses the energy of the contaminant to burn the contaminant through a ‘Self-sustaining’ process

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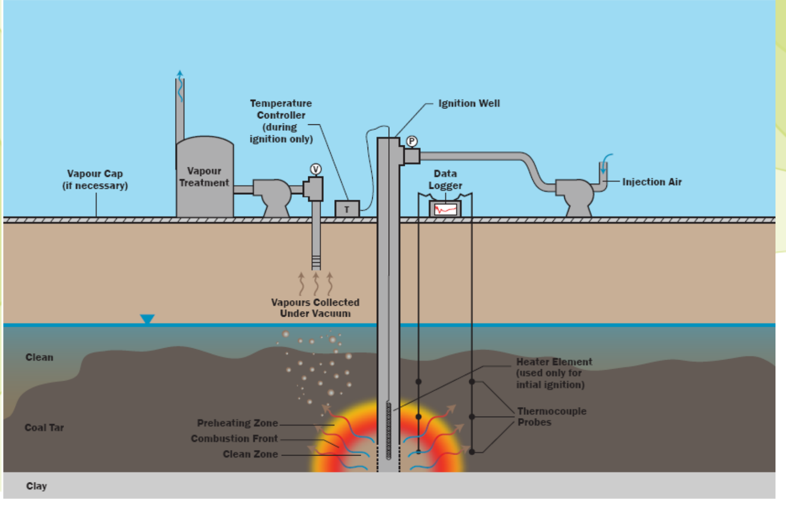
# STAR Application



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# *Exsitu* Field Experiments

**Before**

**Conc (TPH) = 31,000 mg/kg ± 14,000 mg/kg**

**After**

**Conc (TPH) = 10 mg/kg ± 4 mg/kg**



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# *Insitu* Pilot Test

Objectives: Test designed to evaluate STAR:

- At a large scale
- Under saturated conditions (i.e., below ground surface and below the water table)
- Quantify mass destruction rates and remediation efficiency



# Pilot Results

## Post-pilot Soil Sampling

Before

After

# *Insitu* Pilot Test

## Pilot Test Summary

- Almost 5 tons of coal tar destroyed (below ground surface and below the water table)
- Concentration reductions of 3-4 orders of magnitude
- Post-pilot concentrations below Regulators criteria
- Combustion front propagation up to 30 feet/10m observed
- Sustained destruction rates as high at 800 kg/day at a single well
- Continued STAR development planned for Site – complete full-scale implementation by December 2015



# *Insitu* Chemical Methods

- This involves the addition of chemicals to soil or groundwater to oxidise or reduce the contaminants thereby degrading them, reducing their toxicity, changing their solubility, or increasing their susceptibility to other forms of treatment.
- Widely specified, used and accepted in the UK
- Identified as an area of development including improving recovery rates and breakdown rates
- Minimise rebound and residual contamination
- Exploring the sustainability aspects ie can the heat generated be recovered and reused

# *Insitu* Chemical Oxidation Case Study

- Persulphate is a stable solid material and is safe to transport and handle.
- The oxidant does not break down producing any gaseous products (just $SO_4$ with DWS at 250 mg/L)
- The oxidant can be delivered by injection, or via in-situ soil mixing
- Safer to handle than other oxidants that can release gaseous products and cause heat generation



# Persulphate *Insitu* Oxidation Treatability

Arcadis undertook laboratory trials using persulphate

Determine if $S_2O_8$ can degrade $CS_2$

# Pilot Scale Remediation Objectives

- Demonstrate effectiveness of $S_2O_8$ for treating $CS_2$ *in-situ*;
- Verify at field scale the activation chemistry and dosing requirements;
- Evaluate mechanisms for delivering persulphate into the subsurface;
- To validate that the remedial technology can be applied successfully under houses;
- To prove the validation process and communicate to all stakeholders;



# 1946 Site was a Manufacturing Plant

## 1995 Manufacturing plant replaced by Housing Estate



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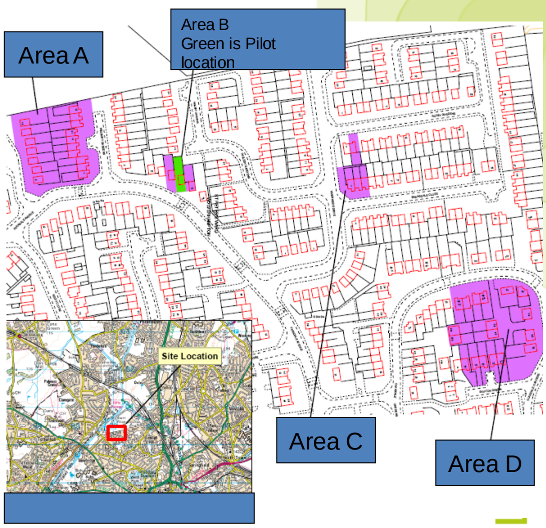
## Pilot Location and Areas identified with possible contamination



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# Delineation

Historical Photo Review

Geophysical Survey
GPR, Magnetic and Electrical Resistivity

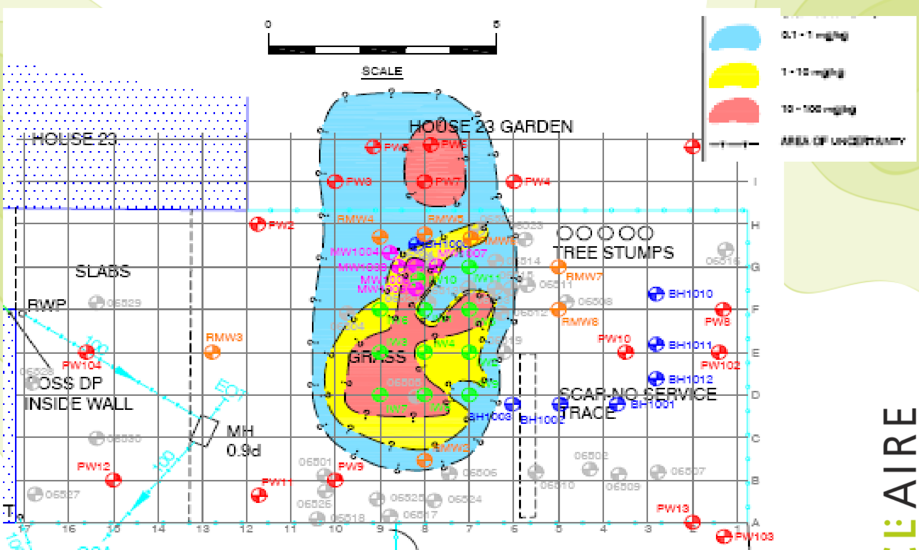
Membrane Interface Probe Survey
85 Probe Points (front and back garden and house)

Soil Coring and Sample Collection
32 Soil Cores Back Garden
5 Soil Cores Front Garden
5 Soil Cores House

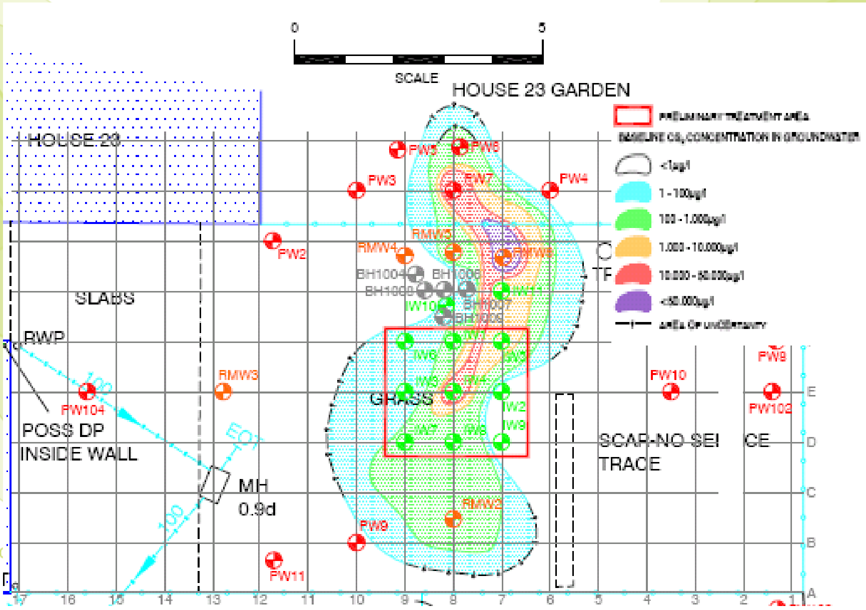
Well Installation and Monitoring of Perched Ground Water



# Baseline $CS_2$ in Soil

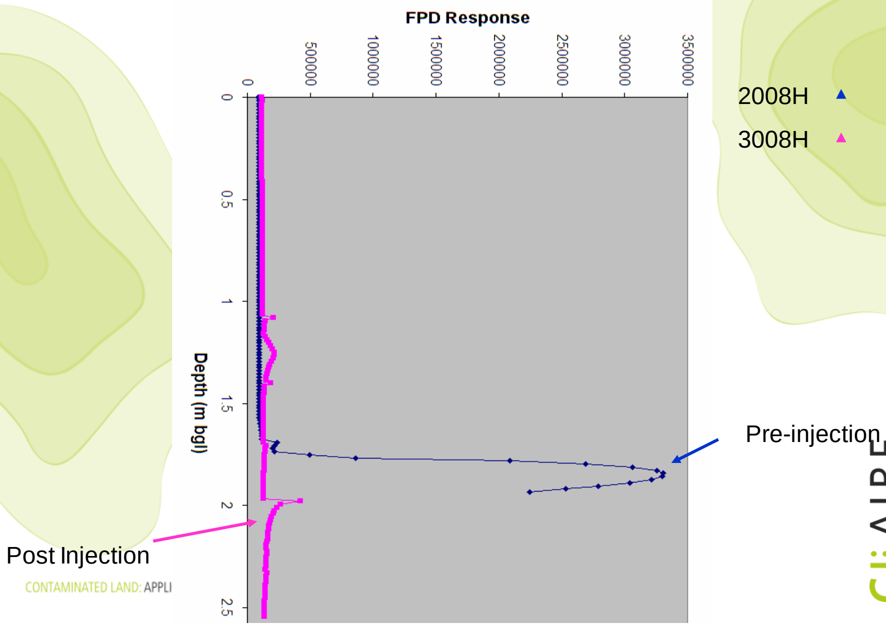


# Baseline $CS_2$ in Perched Water




# Remediation

## MIP confirmation of Treatment



## Full Scale Remediation following Succesful Pilot Study

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## Conclusion

- Four quick case studies all very different
- Novel technologies
- Adaption of mainstream technologies but extending the performance envelopes.
- Successful project application for some difficult contaminants

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## Conclusion: Challenges facing application and uptake

- Adequate site characterisation and good conceptual site model – understanding the problem
- Barrier to entry by consultants. Therefore educating consultants making them aware of what technologies are available. Not always going to the usual suspects
- Ensuring awareness of who provides what technologies and well.
- Understanding the performance envelope of the technology. People always remember when things go wrong.
- People don't want to be first – untried technology (hopefully CL:AIRE helps to provide this confidence)



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**Thank you**

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