Sustainable Remediation

Dr. Cecilia MacLeod, Director
Content

- Remediation of Contaminated Land
- Enhanced Biodegradation
- Chemical Oxidation / Reduction
- Monitored Natural Attenuation
- Physical, Thermal and Other
- Remediation Verification
- Summary and Conclusions
Introduction

• This presentation aims to provide an overview of sustainable approaches to remediation and includes an introduction to in-situ remedial technologies which may be employed to treat both contaminated soils and ground waters.

• The presentation will include a discussion of the technology and how it is used, include some examples and discuss what Lines of Evidence are required to:

  • Monitor the remediation process to ensure that the remediation is targeted in the correct zone
  • Show that remediation is occurring
  • Show that remediation has occurred successfully.
Why Remediate?

• What are the drivers?
  • Improve property value as part of Due Diligence
  • Brownfield redevelopment
  • Legal requirements as condition of planning
  • *Legal requirement under Part 3*
  • Voluntary
What is Remediation?

Breaking or modifying the source – pathway – receptor linkage
Why in- Situ?

Sustainable Remediation

- Avoid excavation and disposal
  - Continuous land filling not sustainable

- UK regulatory guidance on sustainable remediation is being developed
  - Sustainable Remediation Forum (SuRF), responsible for producing regulatory guidance
  - Sustainability has potentially different metrics
  - Use technologies which produce least environmental impact e.g. lower CO₂ emissions
Guidance on Sustainable Remediation

- SURF – UK – Series of Guidance documents available through CLAIRE
- ASTM – Several standards available for Green Remediation
Potential Assessment Criteria for Sustainability

• Future benefits vs costs
• Environmental impact of remediation – is it less than leaving the land untreated
• Environmental impact of performing remediation is minimal and measurable
• Societal impact analysis to assess immediate and long term effects
• Timescale over which the environmental consequences occur, hence inter-generational risk, is part of the decision-making process.
Historical Perspective

• (mid-1990s to mid-2000s)
• In Situ Treatment Technologies

  ▪ Physical:
    • Air Sparge;
    • Soil Vacuum Extraction (SVE);
    • In Situ Chemical Oxidation (ISCO);
    • Fe0 walls

  ▪ Biological:
    • Biosparg;e
    • Biovent;
    • Oxygen and Nutrient Addition;
    • Substrate Addition;
    • Biobarriers
Current Perspective

- (mid-2000s to now)
- Optimization
- Sustainability
- Emerging Contaminants
  - Chlordane
  - 1,4-Dioxane
  - PFOS/PFOA
  - Low Permeability Zones
**Natural Attenuation**

The biodegradation, dispersion, dilution, sorption, volatilization, and/or chemical and biochemical stabilization of contaminants to effectively reduce contaminant toxicity, mobility, or volume to levels that are protective of human health and the ecosystem

(US EPA ORD, OSWER)
History of Natural Attenuation Science

- 1994: ASTM task group formed
- 1995: Draft AFCEE protocol
- 1996: Final AFCEE protocol
- 1997: Draft AFCEE protocol
- 1998: EPA Protocol
- 1999: Final ASTM standard
- 2000: Final EPA Directive
- 2001: EPA Science Advisory Board Review
- 2002: DOE Retrospective
- 2003: DOE Guidance on Enhanced MNA
- 2004: Petroleum hydrocarbons
- 2005: Chlorinated solvents
- 2006: Inorganic contaminants (metals)
- 2007: EPA Technical Basis
- 2008: ITRC Guidance (in progress)
Natural Attenuation

• Naturally occurring processes in soil and ground water that act without human intervention to reduce the mass, toxicity, mobility, volume or concentrations of contaminants

• Biodegradation, dispersion, dilution, absorption, volatilization, and abiotic reactions
Evidence of Natural Attenuation

• Plume Length Should Be =
  Seepage Velocity
  x Time
  ÷ Retardation Factor

• Plume Length Is ..... Shorter
  Thinner
  Appears not to be moving
Natural Attenuation

A Do-Nothing Approach?

Requires quantitative assessment of a plume’s behavior - amount, extent, and rate of travel, as well as long-term evidence of attenuation
Requirements

• Site assessment - hydrogeology, geochemistry, microbiology
• High tech approaches - sampling, analytical, modeling techniques
• Prediction of plume behavior
• May be combined with source.hot spot control
• Containment of dissolved plume
• A risk management strategy
In Situ Bioremediation

In Situ → Bio → Remediation

In Place → Microbial → Method to Fix

Biological agents (bacteria, fungi, plants, or their enzymes) used to clean up pollution in the environment.

Reference: Lisa Alvarez-Cohen, Civil and Environmental Engineering
University of California, Berkeley, Earth Science Division, LBNL
What is Bioremediation??

• Using subsurface microorganisms to transform hazardous contaminants into relatively harmless byproducts, such as ethene and water
  • Biodegrade
  • Mineralize
  • Biotransform

• Techniques or types of bioremediation:
  • A component of Natural Attenuation
  • Enhanced Bioremediation
  • Bioaugmentation
How Does It Work?

- **Growth-Promoting Biological Reduction**

  - **Electron Donor (Food)**
  - **Electron Acceptor (something to breathe)**: [O₂, NO₃⁻, SO₄²⁻, TCE, etc.]
  - **Waste Products**: [CO₂, N₂, FeS₂, Cl⁻]
  - **Energy**

(Drawing Modified from AFCEE and Wiedemeier)
What is In Situ Chemical Oxidation?

- Definition: A technique whereby an oxidant is introduced into the subsurface to chemically oxidize organic contaminants changing them to harmless substances:
  - Rapidly emerging technology
  - Still subject of academic research as well as applied routinely as a commercialized process
  - Several options for selection of oxidant chemicals
  - Requires good understanding of contaminant and site characteristics to ensure effective treatment
OILRIG!

- Oxidation is LOSS of electrons
- Reduction is GAIN of electrons
- The contaminant is oxidised, so something is added that can be reduced
- Contaminants act as electron DONORS
- Additives act as electron ACCEPTORS
ISCO Basics

- ISCO reduces contaminant mass through the oxidation process
- Mass reduction → reduction in risk
- Saturated source and plume treatment
- ISCO maybe combined with another technique (e.g. monitored natural attenuation)
ISC0

http://umweltwirtschaft-uw.de/incore

- Works by injection of chemical oxidants into soil and/or ground water to oxidize contaminants.
  - rapid and **complete** degradation to CO\(_2\) & H\(_2\)O, or
  - **partial** degradation: complex organic molecules into intermediate compounds that can then be subsequently biodegraded

- The common oxidants are:
  - hydrogen peroxide-based Fenton’s reagent, and
  - potassium permanganate.
  - iron (II), manganate (VII),
  - Ozone can also oxidize organic contaminants in situ, but it’s not commonly used
Process of Implementation

Prior to Remediation

During Remediation

After construction / installation
Prior to Remediation

1. Define objectives, identify constraints and options
2. Detailed analysis and assessment
3. Treatability trials
4. Cost-benefit analysis
5. Obtain Regulatory Approval
6. Contractual agreements
<table>
<thead>
<tr>
<th>Example of Stakeholders</th>
<th>Roles</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land owner</td>
<td>Provide access and co-operation, Financially responsible</td>
<td>limit or remove his/her liability</td>
</tr>
<tr>
<td>Developer</td>
<td>Responsible for site remediation and redevelopment.</td>
<td>Redevelopment of site in cost-effective manner / Make Profit</td>
</tr>
<tr>
<td>Local authority</td>
<td>Regulator -</td>
<td>Fulfil duties under Part IIa</td>
</tr>
<tr>
<td>Regulatory authority</td>
<td>Responsible for Special Sites and overseeing remediation of controlled waters</td>
<td>Fulfil statutory responsibilities</td>
</tr>
<tr>
<td>EA/SEPA/NIEA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Contractors / Consultants</td>
<td>May undertake: Site Investigation, Risk Assessment, Remediation and aspects of development</td>
<td>Make profit</td>
</tr>
<tr>
<td>Residents</td>
<td>Consultees</td>
<td>Protect neighborhood/property/selves</td>
</tr>
<tr>
<td>Special interest groups</td>
<td>Consultees</td>
<td>Limit or reduce risk to other environmental / ecological receptors</td>
</tr>
<tr>
<td>Financial institutions</td>
<td>Mortgage or finance provision</td>
<td>Financial Return</td>
</tr>
<tr>
<td>Insurance guarantors</td>
<td>Underwrite risk</td>
<td>Financial Return</td>
</tr>
</tbody>
</table>
“Source → Pathway → Receptor Linkage”
Problems with In-Situ Remediation

- Incomplete Treatment or inadequate treatment of contaminants of concern
  - Poor understanding of contaminant distribution
  - Zone of Influence
  - Sub-surface heterogeneities
During Remediation

- Quality Control
- Monitor
- Re-assess Site Conditions
- Re-evaluate objectives
- Make adjustments to Remediation as necessary
- Liaison with Stakeholders
Completion

- Validate
- Verify
- Monitor
- Decommission
Some Sites to Consider

Site 1 is an industrial site with chlorinated solvent contamination

Site 2 is the Maze Long Kesh site with Hydrocarbon, lead and asbestos contamination

Site 3 is a former industrial estate contaminated with carbon disulphide which was redeveloped for housing pre-Part 2a.
Site 1 - Project Objectives

- The overall objective of the project to implement a remedial strategy to:
  - Permit future redevelopment and use of the two areas of brownfield parcel for future industrial purposes
  - Remediate the site in compliance with the provisions of the Environment Act 1995
Site 1 - Client’s Strategic Objectives

- Site Redevelopment: 3 to 5 years
- Environmental Action: proactive
- Extent of Remediation: once & for all
- Technology Selection: BAT & proven
  - Best Available Technology
**Site 1- Contaminant Profile**

**LITHOLOGICAL SUMMARY**

**Made Ground**
- gross contamination, soil staining
- free product (DNAPL), perched water

**Alluvial Silt / Clay**
- soft, moist silt / clay with no free-flowing groundwater, VOC & SVOC concentrations decrease markedly with depth, except in a few discrete areas
- highly attenuating / absorptive layer (discontinuous across site)

**Peat**

**Sand**
- minor impacts to shallow groundwater, 12-DCA most notable, very limited gw flow, sand layer appears laterally continuous
- clean groundwater - no VOCs detected, freer flowing groundwater, but sand layer is not laterally continuous

**Boulder Clay**
- Top of Boulder Clay has minor levels of some VOCs, but clean beneath the sand lenses

**Sand Discontinuous**

**Boulder Clay**

**Chalk**
- clean groundwater

**Free phase organic liquids**
Site 2 – Key Client Objectives

- Sustainability: CEEQUAL Excellent
- Zero Hazardous Waste Disposal
- Extent of Remediation: Betterment – Site returned to original condition
- Commercial Redevelopment
- Fulfil Regulatory Obligations
Site 2—Technical Challenges

- Protection of Historical Structures
- Stringent Remediation Targets
- Minimise Impact to Neighbors
Site 2- Long Kesh

Geology

- Made Ground – typically 1m
- Deeper within infilled sand extraction <8m
- Superficial Deposits
- Fluvio-Glacial (variable interbedded sand, silt & clay)
- Boulder Clay (variable stiff gravelly clay/silt & silt/sand)
- Between 8.5m bgl and >35mbgl

Sherwood Sandstone - 30 to 50m thick

Hydrogeology and Hydrology

- Sherwood Sandstone – major aquifer of regional importance
- Glacial Deposits – minor aquifer of local importance
- 3 Abstractions ~1km
- Groundwater Flow – tends towards the River Lagan (West)
- River Lagan 250m to West
- Tributary flows around South boundary
- Former surface water drainage flows into tributary
Site 3 – Project Objectives

• Remediate Site using In-situ Remediation Techniques
• Minimal Demolition of Houses
• Minimal Disturbance to Neighbours
• EA and Local Authority Sign off on Voluntary Remediation
Site 3 – Key Client Objectives

• Reputational

• Prevent Blight on Neighborhood
Cross-Section East-West

East

BH06410

West

BH06524

0.2 mg/kg

3.6 mg/kg

128 mg/kg

40.7 mg/kg

0.02 mg/kg

5.9 mg/kg

Carbon disulphide
THANK YOU

• Contact Details
  Cecilia MacLeod  cecilia.macleod@wyg.com

WYG ENVIRONMENT
100 St John Street, London, EC1M 4EH
Tel:  +44 (0)20 7250 7500
Fax:  +44 (0) 20 7250 7501
Mob:  +44 (0)7881 914 370