Dilute and disperse landfills: evidence for natural attenuation

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Study of dilute and disperse sites

- 1974 IGS/DoE survey of landfill sites
  - 56 of 3,000+ sites with potential to seriously pollute surface or ground water

  - The Behaviour of Hazardous Wastes in Landfill Sites

- 1980s continued investigation of some Brown Book sites

- 1990s NRA (now EA) desk study to identify potentially polluting landfills
  - Thriplow selected for study 1996-2002
Phase I
operated 1957 - 1977
household and some commercial/industrial waste
7.2ha, filled to 3 - 9 m bgl
thin soil cover

Phase II
operated 1981 - 1987
household, commercial & industrial waste
4ha, filled to 1.8 - 9 m bgl
contoured “clay” cap
Study objectives

- Characterise plume/s of contaminated groundwater from the landfill
- Identify controls on leachate migration and attenuation
- Develop a well-constrained model for groundwater flow and mass transport
- Provide facilities for long-term monitoring to determine NA processes and test model predictions
Desk study

- Previous investigations
- Groundwater monitoring data from existing boreholes
- Environment Agency/local authority archives (disposal history)
- Aerial photographs
- Meteorological data
Preliminary conceptual model

Landfills previously gravel pits, up to 9 m deep

Leaching may vary seasonally

Contamination identified in BHs to west

Regional gw flow to NW

Vertical flow possibly limited by Plenus Marls
Uncertainties

• Borehole construction and quality of previous monitoring data
• Borehole coverage
• Waste characteristics and leachate quality
• Hydraulic continuity between Middle and Lower Chalk
• Direction, depth and extent of leachate plume
Site investigations 1996 - 97

- CCTV and sampling from 7 of the 11 previously drilled boreholes (1976 - 1993)
- Landfill characterisation (5 new BHs in waste)
  - waste, leachate, porewater, BMP, gas, infiltration
- Surface resistivity imaging (2D)
- Characterisation of Chalk aquifer (1 new BH)
- Groundwater sampling
- Preliminary modelling
Waste characterisation
Significant findings

• Some BH depths at variance with those recorded
• Some BH completions in both Middle and Lower Chalk - distortion of groundwater flow & dilution of leachate?
• Waste in Phase I was more degraded than waste in Phase II (function of age and cover thickness)
• Landfill resistivity appears to reflect leachate front rather than waste - Chalk interface, artefacts below ~ 20 m
• Elevated TOC, Cl and NH₄-N in groundwater downgradient of landfills
• Perimeter resistivity surveys indicate distinct plumes (but one anomaly drilled did not intercept leachate - poor resolution of formation resistivity below 30 m bgl)
Uncertainties

- Drift thickness - geometry of buried channel along western perimeter
- Aquifer properties
- Seasonal variation in groundwater flow
- Calibration of resistivity surveys
- Leachate release from landfill
- Evidence for natural attenuation
Site investigations 1998 - 2002

- 3D resistivity survey of landfill phases
- 6 (No.) BHs in waste/Chalk
- 3 (No.) BHs north of landfill
- Downhole resistivity arrays in new BHs
- Sampling
  - waste, porewater, leachate, groundwater, gas
- Trace organics analyses
- Stable isotope analyses
3D resistivity tomography
Porewater chemistry below waste

Phase I

Phase II

TP13A Ammonium (mg/l)

TP10 Ammonium (mg/l)

Depth (mbgl)

Depth (mbgl)
Time-lapse Monitoring of landfill boreholes to detect transient leachate plumes

Electrode sensors have been permanently installed in landfill boreholes. Monthly monitoring helps to detect transient plumes and seasonal variations in leachate distribution within landfill.

Electrodes on outside of PVC casing ensures electrical contact with surrounding material irrespective of water table.
2D inversion results for prism model

(a) (b) (c)

Fig. 8
ERT inversion images for Borehole TP09

Log Resistivity (ohm.m)

Fig. 10
So, with a better (although not perfect) idea of the waste characteristics, groundwater flow, leachate distribution and flow, is there any evidence for natural attenuation?
Conventional chemistry
Stable isotope findings (S & N)

- Methanogenesis
- Sulphate reduction
- Nitrification
- Denitrification
Enantiomeric forms of Mecoprop

(R) - Rectus

(S) - Sinister

2-(4-chloro-2-methyl phenoxy) - propionic acid
## Biodegradation of mecoprop

<table>
<thead>
<tr>
<th>Redox</th>
<th>R-mecoprop</th>
<th>S-mecoprop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Methanogenic sulphate red.</td>
<td>NO</td>
<td>NO</td>
</tr>
<tr>
<td>Nitrate red.</td>
<td>YES</td>
<td>NO</td>
</tr>
<tr>
<td>Aerobic</td>
<td>YES</td>
<td>YES (faster)</td>
</tr>
</tbody>
</table>
Redox zones

Nitrate reducing zone

Sulphate reducing zone

Methanogenic zone

250 m
Conceptual model (latest)

Variation in groundwater flow direction

Phase I landfill – waste largely degraded, deeper areas below max. groundwater level, no cover

Phase II landfill – undegraded, above maximum groundwater level, completed with clay cover. Evidence of leachate migration through fractures to water table
Uncertainties/challenges

- Access
- Spatial data
- Source term evolution with time
  - a decade of missing data!
- Significance and frequency of pulsed release of leachate
- Any more plumes?