A study of the hydraulic response of landfills to infiltration events

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Sponsors:
Norlands Foundation, 2000 - 2005

Hydrogeological group of the Geological Society of London
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Background and scope of project

- For all materials except those that are non-polluting, it will be necessary to pass water through the landfill to flush out soluble pollutants.
- There is a need to understand how liquid moves, under the specific conditions created within compacted wastes in landfills.
- The study is based on a grid of 20 vibrating wire piezometers (VWPs) installed in the ~1 ha base of a new landfill cell.
- Main aspects investigated:
  - the delay between an infiltration event occurring at the landfill surface (e.g. rainfall or leachate recirculation) and its effects being felt at the base of the landfill;
  - the extent to which intermittent infiltration events at a landfill surface are smoothed and attenuated during downwards vertical flow through unsaturated wastes.
Project details

- The study was undertaken at Beddington Farmlands landfill, Croydon, UK, from July 2000 to January 2006.
- The study was funded by the Norlands Foundation, using Landfill Tax credits.
- The landfill was operated by Thames Waste Management Ltd at the start of the study, and since 2005 by Viridor Waste Management Ltd.
- Follow-on funding has been obtained from the Environment Agency for a further 2 years experimental work.
Leachate Management

November 2000
June 2001

Clay cap

Waste Tyres

Slotted pipe, 125mm, with 10mm holes

Solid pipe, 300mm

December 2001:
Leachate recirculation trench installed;
access pipes R3 and R4

Leachate recirculation trench installed;
access pipes R3 and R4
Data output from study

[Graphs and charts showing data over time]
Aspects investigated

Completed or on-going
• Performance of equipment
• Performance of drainage blanket over 7 years+
• Response of heads to rainfall events during infilling
• Response of heads to abstraction events
  – estimates of drainable porosity
• Recovery of heads when recirculation interrupted
Under way
• Response to injection of water/leachate
Future possibilities
• Tracer trial during injection of water/leachate
• Flushing trials

Performance of equipment

Routine level monitoring at sump

VWPs:
- Long term downward drift, slow, ~linear.
  600 – 1200mm/a
Results 1. Performance of drainage blanket

Initial development of leachate heads in the ‘C’ line piezometers, October to December 2000

Comparison of responses to hydraulic events, December 2006 to Feb 2007
Results 2. Response of leachate heads to rainfall events

<table>
<thead>
<tr>
<th>Date</th>
<th>Head (m)</th>
<th>Rainfall (mm)</th>
<th>Lag time (days)</th>
<th>Head increase (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>9/10/00</td>
<td>0.5</td>
<td>27.4</td>
<td>&lt;0.5</td>
<td>C5: ~1,000</td>
</tr>
<tr>
<td>29/10/00</td>
<td>1.5</td>
<td>26.8</td>
<td>&lt;0.5</td>
<td>C3-C5: ~150</td>
</tr>
<tr>
<td>7/12/00-12/12/00</td>
<td>5</td>
<td>48</td>
<td>-2</td>
<td>C1-C5: ~450</td>
</tr>
<tr>
<td>3/12/00-4/1/01</td>
<td>6.7</td>
<td>39.3</td>
<td>-3</td>
<td>&lt;50</td>
</tr>
<tr>
<td>21/1-01-26/1/01</td>
<td>6</td>
<td>38.6</td>
<td>None</td>
<td>Measurable</td>
</tr>
</tbody>
</table>

Results 3. Response of leachate heads to abstraction

<table>
<thead>
<tr>
<th>Date</th>
<th>Head (m)</th>
<th>Apparent drainable porosity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>May-Jun 2001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>29/05/01</td>
<td>411</td>
<td>3.4</td>
</tr>
<tr>
<td>30/05/01</td>
<td>274</td>
<td>5.1</td>
</tr>
<tr>
<td>02/06/01</td>
<td>246</td>
<td>2.5</td>
</tr>
<tr>
<td>05/06/01</td>
<td>289</td>
<td>4.8</td>
</tr>
<tr>
<td>07/06/01</td>
<td>344</td>
<td>0.5</td>
</tr>
<tr>
<td>11/06/01</td>
<td>195</td>
<td>0.7</td>
</tr>
</tbody>
</table>

- For MSW up to 1 year old, mean drainable porosity was ~4.6% v/v, [range 2.5 – 6.5%]
- Values ranging 0.8 - 1.6% obtained after 5+ years (mean 1.2%)
Results 4. Head recovery after pumping stops

- Results show ‘drain-down’ continuing for at least 48 days following cessation of pumping.
- Total increase in leachate head of up to 2.1m
- While pumping continues, heads decline or remain stable, regardless of whether the abstracted leachate is re-injected or removed from site.

<table>
<thead>
<tr>
<th>Pumping Date</th>
<th>Pumping/Re-starts</th>
<th>Interval</th>
<th>Overall Recovery</th>
<th>Initial Recovery Rate</th>
<th>Final Recovery Rate</th>
<th>Average Recovery Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>17/08/01</td>
<td>18/07/01</td>
<td>30</td>
<td>1500</td>
<td>74</td>
<td>14</td>
<td>42</td>
</tr>
<tr>
<td>19/12/01</td>
<td>09/11/01</td>
<td>40</td>
<td>1678</td>
<td>167</td>
<td>19</td>
<td>42</td>
</tr>
<tr>
<td>07/11/05</td>
<td>20/09/05</td>
<td>48</td>
<td>~linear</td>
<td>~linear</td>
<td>~linear</td>
<td>44</td>
</tr>
</tbody>
</table>

Modelling of head recovery (White, Beaven)

1-D model calibrated against Beddington data
Response of heads to water injection, January 2007

-8.0 -7.0 -6.0 -5.0 -4.0 -3.0 -2.0 -1.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0

-8.0 -7.0 -6.0 -5.0 -4.0 -3.0 -2.0 -1.0 1.0 2.0 3.0 4.0 5.0 6.0 7.0

1-Dec-06 8-Dec-06 15-Dec-06 22-Dec-06 29-Dec-06 5-Jan-07 12-Jan-07 19-Jan-07 26-Jan-07 2-Feb-07 9-Feb-07

Head rise at top (SE) corner of cell, C1 2.5 m
Head rise at sump (NW) corner of cell, C5 4 m
Area of cell base 9,000 m²
Assume saturated storage coefficient 1.2 % v/v
Volume from 1.5m to 4.0m depth
9000m² x 2.5 x 1.2% 270 m³
Volume from 0 to 1.5m depth
1/3 x 9000m² x 1.5m x 1.2% 45 m³
Recorded volume of water injected xxxx m³

Injection wells, October 2007

Flanged well head fittings
Clay cap
depth 2-3m in waste
Waste
drilling diameter 400 – 500mm
casing diameter ~200mm

Connection to gas extraction system
Bentonite pellets to surface
Gravel pack to 0.5m above slotted casing
Slotted casing from 1m below cap

Pumped supply from Cells 2, 3 and 4
Bowser
Flow totaliser
Well 1
Well 2
Well 3
Pumped supply from leachate holding tank

Results 5. Temperatures recorded by VWPs

- Approximately linear rise during first 4 years
- Still rising, but at a decreasing rate
- Currently ~35°C on cell base, ±
- Some anomalies e.g. water injection 2007

CONCLUSIONS

- Gravel drainage layer remains effective at equalising heads across cell base after 7 years. Little or no evidence of any differential responses.
- Lag time for 20-50mm rain events increased from <12 hours for 2m waste depth, to ~2 days for 5m waste depth.
- Above ~9m waste depth, rain events of this magnitude produced no discrete response at the site base.
- Rapidly drainable porosity ranged from 2.5 to 6.5 %v/v (mean ~4.6%) for fresh MSW, similar to other studies.
- Average value of 1.2% after 5-7 years indicates a significant decrease in drainable porosity.
- Ultimate drainable porosity is greater, as shown by continuing drain-down after cessation of abstraction.
- Still a need to do large volume re-injections under the cap, to assess lag times etc. for high rate recirculation.