Local Practices Managing CCRs

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wood.
Outline

• Leachate collection systems (chimney drain origins)
• Liner system performance
• Cover system lessons learned - infiltration water management
• CCR management trends
Leachate Collection Systems: Background

- MSW vs. Ash Landfills

MSW Landfill

Ash Landfill
## Background: MSW vs. Ash Landfills

<table>
<thead>
<tr>
<th>Physical Property</th>
<th>MSW</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grain Size</td>
<td>Highly Variable</td>
<td>80% + passing No. 200 = Non Plastic Silt</td>
</tr>
<tr>
<td>Porosity</td>
<td>0.4 to 0.62</td>
<td>0.44</td>
</tr>
<tr>
<td></td>
<td>(Qian, Koerner, Gray, 2002)</td>
<td></td>
</tr>
<tr>
<td>Permeability</td>
<td>$4 \times 10^{-2}$ to $9 \times 10^{-4}$ cm/sec</td>
<td>$1 \times 10^{-5}$ cm/sec</td>
</tr>
<tr>
<td></td>
<td>(Qian, Koerner, Gray, 2002)</td>
<td></td>
</tr>
<tr>
<td>Leachate Generation</td>
<td>600 to 1,400 gpad</td>
<td>500 to 900 gpad</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Operations</th>
<th>MSW</th>
<th>Ash</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active Face</td>
<td>Small (1 Acre)</td>
<td>As large as allowed/reasonable</td>
</tr>
<tr>
<td>Operational Cover</td>
<td>Daily Soil (6 inches)</td>
<td>Initially weekly soil (6 inches)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Modified to periodic soil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Modified to soil alternative</td>
</tr>
<tr>
<td>Leachate Generation</td>
<td>Reduce</td>
<td>Initially (2000’s) – Little Concern</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Now – Reduce</td>
</tr>
</tbody>
</table>
Ash landfill circa 2009: Sump blinded by protective cover sedimentation during initial ash filling
Ash Landfill Sump

Ash landfill circa 2009: Sump blinded by protective cover and ash sedimentation during initial ash filling
Ash landfill circa 2009: Sump blinded by ash sedimentation during initial ash filling

Ash landfill circa 2009: LCS laterals blinded by ash sedimentation during initial ash filling
Problem and Solution…

• Problem
  - Larger quantity of stormwater runoff from ash and protective cover (unlike MSW landfills)
  - Protective cover soil and ash eroding
  - Deposited downslope at leachate collection sumps
  - Blinded ordinary (MSW-style) sumps and leachate collection system (LCS) corridors

• Solution
  - Operations Plans
  - Grading Plans
  - Chimney Drains – combination of:
    • erosion and sediment control
    • graded filter design
    • Stormwater design
Evolution: The Next Ash Landfill…

Ash landfill circa 2010: Infiltration zone and chimney drain layout
Evolution: The Next Ash Landfill...

Chimney Drain (left) LCS Corridor center (raised with graded filter)

Graded Filters (Check Dams)
Evolution: The Next Ash Landfill…

Chimney Drain/Infiltration Zone – No. 57 Stone

Chimney Drain/Infiltration Zone – No. 57 Stone with Bottom Ash
Evolution: The Next Ash Landfill...

Ash landfill circa 2017: Chimney Drain Detail
• Leachate collection systems (chimney drain origins)
• Liner system performance
• Purpose
  ➢ Liners leak, but how much?
  ➢ Unique situation to review data from double-lined CCR landfills
  ➢ Evaluate leachate flow from leak detection layers
  ➢ Available liner system performance data

• Driver for double-lined CCR landfills
  ➢ Overfills – new CCR landfills over existing ash ponds
  ➢ Groundwater monitoring isolation - new from old
  ➢ Redundancy ~ belt and suspenders

• 4 Facilities – Southeastern US

## Facility Summary

<table>
<thead>
<tr>
<th>Facility</th>
<th>Cell</th>
<th>Average annual rainfall in (mm)</th>
<th>GW separation distance ft (m)</th>
<th>Cell area acres (hectares)</th>
<th>Max waste height ft (m)</th>
<th>LDS collector spacing ft (m)</th>
<th>Base slope (%)</th>
<th>End construction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>41.6</td>
<td>20 (6.1)</td>
<td>10.8 (4.4)</td>
<td>40 (12)</td>
<td>350 (107)</td>
<td>2.4 to 3.5</td>
<td>June 2009</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>41.6</td>
<td>9 (2.7)</td>
<td>13.8 (5.6)</td>
<td>45 (14)</td>
<td>350 (107)</td>
<td>3.5</td>
<td>June 2010</td>
</tr>
<tr>
<td>2</td>
<td>1</td>
<td>44.9</td>
<td>8 (2.4)</td>
<td>9.9 (4.0)</td>
<td>40 (12)</td>
<td>274 (83)</td>
<td>4</td>
<td>October 2010</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>44.9</td>
<td>8 (2.4)</td>
<td>9.6 (3.9)</td>
<td>40 (12)</td>
<td>274 (83)</td>
<td>4</td>
<td>October 2010</td>
</tr>
<tr>
<td>3</td>
<td>1</td>
<td>45.4</td>
<td>4 (1.2)</td>
<td>31.0 (12.6)</td>
<td>20 (6)</td>
<td>150 (46)</td>
<td>5</td>
<td>June 2014</td>
</tr>
<tr>
<td>4</td>
<td>1</td>
<td>45.5</td>
<td>30 (9.1)</td>
<td>23.5 (9.5)</td>
<td>35 (10.7)</td>
<td>220 (67)</td>
<td>5</td>
<td>June 2015</td>
</tr>
</tbody>
</table>

- Flow measurement by totalizing flow meters
- Data acquisition varied from manual recording to electronic
- Facilities constructed with third-party CQA
Site 1 – Leak Detection System Flow

- Total avg leakage
  - Cell 1 = 2.6 gpad
  - Cell 2 = 2.0 gpad
- IRLR = 300 gpad
- ALR = 500 gpad
Site 2 – Leak Detection System Flow

- Total avg leakage
  - Cell 1 = 0.5 gpad
  - Cell 2 = 2.8 gpad
- IRLR = 300 gpad
- ALR = 500 gpad
Site 3 – Leak Detection System Flow

- Total avg leakage = 0.7 gpad
- IRLR = 300 gpad
- ALR = 500 gpad
Site 4 – Leak Detection System Flow

- Total avg leakage = 2.8 gpad
- IRLR = 81 gpad
- ALR = 141 gpad
# Leak Detection System Flow Summary

<table>
<thead>
<tr>
<th>Facility</th>
<th>Cell</th>
<th>Time months</th>
<th>Average flow (gpad)</th>
<th>Average flow (lphd)</th>
<th>Max flow (gpad)</th>
<th>Max flow (lphd)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>83</td>
<td>2.6</td>
<td>24.4</td>
<td>73</td>
<td>683</td>
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<td>1</td>
<td>2</td>
<td>64</td>
<td>2.0</td>
<td>18.3</td>
<td>34</td>
<td>318</td>
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<tr>
<td>2</td>
<td>1</td>
<td>71</td>
<td>0.5</td>
<td>4.9</td>
<td>9.4</td>
<td>88</td>
</tr>
<tr>
<td>2</td>
<td>2</td>
<td>71</td>
<td>2.8</td>
<td>25.8</td>
<td>128</td>
<td>1,200</td>
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<tr>
<td>3</td>
<td>1</td>
<td>25</td>
<td>0.7</td>
<td>6.5</td>
<td>56</td>
<td>525</td>
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<tr>
<td>4</td>
<td>1</td>
<td>24</td>
<td>2.9</td>
<td>26.7</td>
<td>61</td>
<td>571</td>
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</tbody>
</table>

- **Average flows (gpad)**
  - Min = 0.5 gpad
  - Max = 2.8 gpad
  - Avg = 1.9 gpad

- **Max flows (gpad)**
  - Min = 9.4 gpad
  - Max = 128 gpad
  - Avg = 60 gpad
Design Application

• Inform action leakage rate determination
  - Initial Response Leakage Rate (IRLR) = 300 gpad
  - Action Leakage Rate (ALR) = 500 gpad

• Typical approach
  - Designer’s assume a certain number and size of defects to evaluate liner performance
  - Typical assumption is 1 to 4 defects/acre for good CQA
  - Defect size 1mm = leakage of 105 gpad/defect (at 1 ft head)

• Back-calculated defect frequency from LDS flows
  - \[ Q = C_b \cdot a \cdot (2 \cdot g \cdot h)^{0.5} \]
  - Q = flow rate through geomembrane
  - \( C_b \) = flow coefficient (0.6 for circular hole)
  - a = area of circular hole
  - g = acceleration due to gravity
  - h = liquid head above the liner

(Qian, X., Koerner, R., Gray, D., 2002)
### Design Application

<table>
<thead>
<tr>
<th>Facility</th>
<th>Area (ac)</th>
<th>Measured Leakage (gpad)</th>
<th>Head Condition (ft)</th>
<th>Leakage per Defect (gal/defect/day)</th>
<th>Equivalent No. of Defects (N/ac)</th>
<th>Estimated Total No. of Defects</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>24.6</td>
<td>2.30</td>
<td>1</td>
<td>105</td>
<td>0.022</td>
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<td>0.023</td>
<td>16</td>
<td>0.146</td>
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<td>2</td>
<td>19.50</td>
<td>3.30</td>
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<td>105</td>
<td>0.031</td>
<td>0.6</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>0.028</td>
<td>17</td>
<td>0.189</td>
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<tr>
<td>3</td>
<td>31.00</td>
<td>0.70</td>
<td>1</td>
<td>105</td>
<td>0.007</td>
<td>0.2</td>
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<td></td>
<td></td>
<td>0.021</td>
<td>15</td>
<td>0.046</td>
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<tr>
<td>4</td>
<td>23.50</td>
<td>2.80</td>
<td>1</td>
<td>105</td>
<td>0.027</td>
<td>0.6</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>0.023</td>
<td>16</td>
<td>0.177</td>
</tr>
</tbody>
</table>

- Two head conditions (h) considered
  - h = 1 ft → regulatory maximum
  - h = 0.021 to 0.028 ft → geocomposite drainage (geonet) thickness

- Based on 2 cm diameter circular defect
Conclusions

• Low leakage rates
  - two orders of magnitude below IRLR and ALR

• Data shows that CCR landfill primary liner systems perform well

• Results comparable with other studies
  - USEPA 1992 (Bonaparte & Gross, LDCRS flow from double-lined landfills and surface impoundments)
  - three landfills = seven cells (group 1 = GM top liner and geonet LDS)
  - average flow rates = 0 to 22 gpad (0 to 220 lphd)
  - max flow rates = 11 to 86 (110 to 860 lphd)
  - with CQA leakage less than 100 gpad (1,000 lphd)
  - without CQA leakage greater than 100 gpad (1,000 lphd)
Outline

• Leachate collection systems (chimney drain origins)
• Liner system performance
• Cover system lessons learned - infiltration water management
Cover System - Infiltration Water Management: Background

- Operations 1984 - 2004
- Closed 2008
- West Area = 38 acres soil-geosynthetic cover
- East Area = 14 acres soil cover

Cover System - Infiltration Water Management: Background

60 to 80 ft Vertical Elevation Change
Infiltration water: cover system termination – key trench and outlet pipe (2007 design)

100 ft Spacing
Infiltration water: cover system termination – key trench (2007 design)

Finished cover subgrade before key trench excavation

Key trench excavation – “rough” key trench corners
Infiltration water: cover system termination – key trench (2007 design)

Geomembrane deployed in key trench

Geocomposite deployed in key trench
Infiltration water: cover system termination – key trench (2007 design)

Backfilling key trench: geosynthetic cover to the right; “flat area” (ash) to receive soil cover to the left
Pavement edge-drain used as panel drain: aggregate and geotextile wrap added

Connection for pipe outlet – spaced 100 ft on center
Infiltration water: panel drain outlet (2007 design)

Assembled panel drain (prior to pipe connection)

Completed panel drain installation
Ash boil at northeast perimeter (2009)

- Construction completed Fall 2008
- November 2009 boils developed after significant rainfall event
Settlement and deformation northeast perimeter (2009)

Linear settlement feature

Linear settlement feature – up close
Perimeter cover settlement and boils (2009)

2009 Response Actions:
• Notify state permitting agency
• Cleanup and assess
• Monitor
Key trench – uncovered (2011)

Evidence of water flow and ash transport in key trench side wall

Subgrade void spaces filled with ash at key trench inside crest
Settlement and deformation uncovered northeast perimeter (2011)

Cover soil removed and geomembrane exposed

Geomembrane removed – ash loss/undercutting at perimeter exposed
2011: Retrofit - install perimeter drain

- Perforated pipe
- Drainage aggregate
- Non-woven geotextile
- 2 outlets at NW and NE downslope
Recurrences and retrofit

• 2012:
  - Boil and linear settlement recurred NW
  - NE stable with clear water discharge
  - Retrofit NW with additional perimeter drain outlets

• 2015: Boil at NW

• 2016: Retrofit – Continuous outlet
  - Geocomposite/aggregate extending to toe

• 2019 – Satisfactory performance
2016 Retrofit – Continuous outlet
2016 Retrofit – Continuous outlet

CHANNEL

OVEREXCAVATE 2-FT BEYOND, BEHIND, AND BELOW KEY TRENCH/PERIMETER DRAIN

ACTUAL DIMENSION MAY VARY

EDGE OF LINER MARKER (SEE NOTE #2)

DAYLIGHT 40-MIL GEOMEMBRANE AND GEOCOMPPOSITE FLAPS AT SLOPE FACE

OVEREXCAVATE 2-FT BEYOND, BEHIND, AND BELOW KEY TRENCH/PERIMETER DRAIN

compacted structural backfill

approximate location of removed perimeter drain

SEW GEOCOMPPOSITE DRAINAGE LAYER EXTENSION

40-MIL GEOMEMBRANE WELD

1/2-ZS/5' NONWOVEN GEOTEXTILE

NCDOT #67 CLEAN WASHED STONE

ORIGINAL COVER SYSTEM LIMIT

RESTORED 6'' VEGETATIVE COVER LAYER

COMPACTED STRUCTURAL FILL

OVER POSI

1' MIN

6'

2.5'

2'

11'

4'
Remove and backfill the key trench – restore subgrade

Geomembrane flap – to direct infiltration water to perimeter
2016 Retrofit – Continuous outlet

Continuous outlet – after construction (2016)

Continuous outlet – April 2017
Cover System - Infiltration Water Management: Conclusions

- Original cover termination was susceptible to water intrusion
- Flow conduits existed, were created, and expanded
- Ash transport and deformation only along slopes of 3 to 6%
- Boils emerged at the low (downstream) end of the slope
- Take-aways…
  - Cover system perimeter terminations are critical
  - Infiltration water must be outlet with confidence
  - Construction quality is important – intimate contact between geomembrane and subgrade matters for cover system too
  - Applicable to ash pond closures
Outline

• Leachate collection systems (chimney drain origins)
• Liner system performance
• Cover system lessons learned - infiltration water management
• CCR management trends
CCR management trends

• Beneficial reuse
  ➢ State law requiring beneficial reuse (NC and VA)
  ➢ Sluiced ash differs from generation ash
    • Mixed fly and bottom ash
    • Carbon content
    • Organics
  ➢ Demand dictates pace of removal – 300,000 to 400,000 tons/year
    • Removal rate influence closure duration
    • Longer closure durations may not be regulatory deadlines
  ➢ Longer duration closure consider…
    • Increased contact water and wastewater treatment volumes
    • Longer dewatering efforts
  ➢ Future mining? Consider characterizing ash during closure
CCR management trends

• Ash pond instrumentation & monitoring
  ➢ Equipment access and construction stability
  ➢ Design performance

• Closure in place to closure by removal
  ➢ Site proposed/planned for in place closure…
  ➢ Required to close by removal (VA and NC)
  ➢ Voluntary closure by removal
  ➢ Removal takes more time and increases costs

• Geomembrane applications
  ➢ Lined retention ponds
  ➢ Lined leachate tanks
  ➢ Temporary rain cover

• Alternative cover systems
Questions?

Thank You For Attending!

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