Landfill Leachate Impacts from Coal Ash and Exploration & Production Wastes

NEW YORK SOLID WASTE ASSOCIATIONS SOLID WASTE/RECYCLING CONFERENCE & TRADE SHOW

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Introduction

- Mixed Waste and Coal Ash Landfills
- E&P Waste Generation
- What’s in These Wastes - Leachate Concentrations
- What are the Impacts on Leachate Composition
- Considerations for Treatment Design & Operations
- Conclusions
Coal Fired Power Plant Waste Sources

- Flue gas desulfurization (FGD) wastewater
- Fly ash transport water
- Bottom ash transport water
- Flue gas mercury (Hg) control wastes
- Gasification process discharges
- Combustion residual leachate from ash/FGD ponds and landfills
CC- Coal Combustion Residuals
Types of Coal Power Plant Wastes

► Fly Ash

- Ash collected by particulate control equipment
- Fine grained, silt-size
- Spherical, well-graded within the fine fraction
- Class F non-cementing from eastern coal – no cohesion
- Class C self-cementing from western coal
- Dry Density 65 to 90 pcf
- Friction angle 25° to 45°; typical 30° to 35°
- Permeability 10^{-4} to 10^{-6} cm/sec; typical 5x10^{-4} cm/sec
Types of Coal Power Plant Wastes

► Bottom Ash
  - Ash that falls to bottom of boiler
  - Fine to coarse grained, sand size
  - Angular, well-graded
  - Dry Density 65 to 100 pcf
  - Friction angle $25^\circ$ to $45^\circ$; typical $35^\circ$ to $40^\circ$
  - Permeability $10^{-1}$ to $10^{-3}$ cm/sec; typical $5 \times 10^{-3}$ cm/sec

► Boiler Slag is similar to Bottom Ash – but more coarse. Not usually a factor in regard to engineering properties – low quantity of total waste
Types of Coal Power Plant Wastes

► Flue Gas Desulfurization (FGD)

- By-product of scrubber system used to reduce sulfur dioxide – scrubbers utilize lime or pulverized limestone
- Fine grained, silt size; similar to fly ash
- Ranges from no cohesion (synthetic gypsum) to self-cementing; variable depending on system
- Dry Density 65 to 90 pcf
- Permeability $10^{-4}$ to $10^{-7}$ cm/sec; depends on Calcium Sulfate (gypsum) or Calcium Sulfite (wet or dry scrubber and/or whether or not there is forced oxidation)
- 33 sites in 15 states
- Varies by coal type and combustion/collection process
- Constituents are highest in FGD leachate, then in ash landfill leachate, and then in ash impoundment samples.
- CCR leachates are moderately to strongly alkaline regardless of coal type or process.

Univ Wisconsin Studies
- Looked at leachate concentrations & ionic strength
- High ionic strength caused higher permeability of clay & GCL liners.
CCR and MSW Leachate Comparison

- Fly ash leachates (39 samples) showed low ionic strength (< 0.2 M)
- Fly Ash/Bottom Ash Mixtures. Fly ash/bottom ash leachates (24 samples) also showed low ionic strength (< 0.2 M),
- FGD Waste. Flue gas desulfurization (FGD) leachates (5 samples) showed the highest ionic strengths (up to 0.42 M) and the highest magnesium and sodium concentrations (Na ~ 5,000 mg/L),
- The highest hydraulic conductivity value was associated with a leachate sample collected from an FGD impoundment where sluice water was recirculated, resulting in a highly concentrated leachate.
- • FGD/Fly Ash/Bottom Ash Mixtures. Facilities with blends of FGD waste and ash (8 samples), showed much lower ionic strengths (<0.13 M) than FGD waste alone,
- MSW Leachate – Higher ionic strength and variable constituents

Coal Ash Leachate Factors

- Calcium in fly ash influences pH of the ash–water system.
- Mobility of most elements in ash is pH sensitive.
- Alkalinity of fly ash attenuates release of Cd, Co, Cu, Hg, Ni, Pb, Sn or Zn.
- High alkalinity increases release of oxyanionic species such as As, B, Cr, Mo, Sb, Se, V and W.
- Precipitation of secondary phases (ettringite) captures and binds As, B, Cr, Sb, Se and V.
- Concentrations of monovalent and divalent ions (chlorides, calcium, also boron)
Range of Constituents in Ash Landfill Leachate

Univ Wisconsin Study
CEC Leachate Investigations

- IL Coal Ash (Flyash/Gypsum/Bottom Ash/FGD Blowdown
  - Boron 260 to >500 mg/L; minimal heavy metals
- IN Mixed Waste MSW County LF
  - Coal Ash and MSW
- GA MSW Mixed Waste Ash LF
  - Fly Ash & Bottom Ash as daily cover
- WV Coal Ash Mixed Waste LF
  - Fly Ash, bottom Ash, CCR at Power Plant
- SC Mixed Waste LF
  - Mostly Coal Ash with Off-spec products and wood pallets
- PA Coal Ash LF
  - Power Plant Monofill
- E&P Wastes and Ionic Strength
  - 15 sites minimal to 50% E&P Wastes
## CEC Leachate Investigations

<table>
<thead>
<tr>
<th>Site</th>
<th>As, ug/l</th>
<th>Hg, ng/l</th>
<th>Se, ug/l</th>
<th>Cl, mg/l</th>
<th>Na, mg/l</th>
<th>B, mg/l</th>
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<td>ELGs</td>
<td>6/8</td>
<td>119/242</td>
<td>NA</td>
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<td>NA</td>
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<td>IN</td>
<td>143 - 421</td>
<td>910 – 9,220</td>
<td>165 - 408</td>
<td>3,590 – 10,100</td>
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<td>GA</td>
<td>23.6 – 63.6</td>
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<td>25 – 50</td>
<td>3,200</td>
<td>3,510 – 3,900</td>
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<td>WV</td>
<td>110 – 1,600</td>
<td>Not Reported</td>
<td>41 – 110</td>
<td>180-400</td>
<td>180-400</td>
<td>1.9</td>
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<tr>
<td>SC</td>
<td>50 – 4,830</td>
<td>&lt;2</td>
<td>20 – 80</td>
<td>Not Reported</td>
<td>60 – 3,140</td>
<td>Not Reported</td>
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<td>PA</td>
<td>5 – 1,330</td>
<td>Not Reported</td>
<td>&lt;5 – 1,330</td>
<td>9.25 – 1,090</td>
<td>14.8 – 3,700</td>
<td>0.07 – 3.69</td>
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<tr>
<td>Ash Leachate</td>
<td>0.8 – 1,300</td>
<td>0.5 - 80</td>
<td>0.08 – ~2,000</td>
<td>Not Reported</td>
<td>Not Reported</td>
<td>Not Reported</td>
</tr>
<tr>
<td>E&amp;P (15) Sites</td>
<td>ND</td>
<td>ND</td>
<td>ND</td>
<td>630 – 8,224</td>
<td>429 – 4,005</td>
<td>Not Reported</td>
</tr>
</tbody>
</table>
Comparison of Ionic Strengths

RMD = Relative Abundance of Mono and Divalent ions

Plotted against Ionic strength

EPRI 2006
E & P Background

- Unconventional gas/oil E&P ongoing in NE U.S. for 10 years, very hot and heavy the last 5 years, but recently slowed, and now picking up.

- Large tonnages of solids, semi-solids and solidified liquids have been disposed in landfills over the recent past years.

- There is a large and “accurate” database for E&P chemical composition, waste types placed, tonnages and percent of overall total, and leachate analyses.

- Collectively, these data allow us to evaluate if E&P wastes are, or have the potential to, impact leachate quality.
E&P Wastes

► Evaluate 14 landfills in PA, WV & OH accepting E&P waste + 5 “control landfills”.

► Quantify E&P waste types disposed.

► Determine leachate parameters of interest.

► Evaluate effect these parameters may have on leachate chemistry.

► Assess potential impact the changes in leachate chemistry may have on leachate treatment.

► Determine other areas needing research/evaluation.
E&P Return Waste Generation

Flowback, Brine, Produced Water → Settling → Thickening → Chemical Treatment → Effluent

Drilling Mud → Settling → Thickening → Solidification → Landfill

→ Process Liquid

→ Solids

Source: Countess, et al, 2014
Volume and Types of E&P Wastes Being Generated

► In 2014-2015, 1.5 to 2.0 million tons of E&P waste is disposed annually in tri-state area (PA, OH, WV).

► Wastes include:
  ▪ Solids – drill cuttings, frac sand
  ▪ Semi-Solids/Liquids – spent muds, sediment, produced water, brine, drilling/fracing fluids
Volume and Types of E&P Wastes Being Generated

- E&P wastes are 5% to 10% of total waste tonnage being disposed annually in tri-state area

- Nineteen landfills in this study
  - 10 different companies/authorities
  - Started accepting E&P wastes 2011-2012
  - At 10 sites E&P is 10% to >50% of total tonnage (avg. 25%)
  - At 4 sites E&P is 2% to 10% of total tonnage
  - Ranging from 10,000 to 165,000 TPY
  - Study showed liquid wastes accepted for solidification very minor

- Five “control” landfills in this study
  - Accept no E&P waste
  - In same region as study sites
What’s In E&P Waste

► What’s Available (Source: Countess, et al, 2014)

<table>
<thead>
<tr>
<th>Concentration</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt; 10 g/kg</td>
<td>Al, Ca, Ba, Fe, Na</td>
</tr>
<tr>
<td>1-10 g/kg</td>
<td>K, Mn, Mg, Sr</td>
</tr>
<tr>
<td>0.1-1 g/kg</td>
<td>B, Br, Li, P, Pb, Si, V, Zn</td>
</tr>
<tr>
<td>&lt; 0.1 g/kg</td>
<td>Numerous</td>
</tr>
<tr>
<td>???</td>
<td>Organics</td>
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</tbody>
</table>

► What Can Leach
- Numerous TCLP & SPLP results
- Ba, Ca, K, Na, Mg, Mn, Sr, V, chlorides, sulfates
Impacts on Leachate Composition

► Evaluations Performed

• Inter-Site (are parameter concentrations different between sites, do differences correlate to tonnages/percentages of E&P waste?)
• Intra-Site (for each site, are parameter concentrations different pre- versus post-E&P acceptance?)

► Analysis for Each Landfill

• Looked at Ba, K, Na, V, TDS, chlorides and sulfates
• Evaluated quarterly data from 2007 thru 2015 (2nd Qtr.)
• Separated data into pre-E&P waste acceptance and post-E&P waste acceptance
• Developed time series plots and descriptive statistics for each parameter
• Performed t-Test, 2-sample unequal variance at 95% confidence for pre- versus post-E&P
Impacts on Leachate Composition

► Inter-Site Comparison

- For each parameter evaluated, ranked the sites from highest average concentration to lowest
- Calculated an average rank for each site

► Key to Following Tables

- RED TEXT – Site disposes 10% to >50% E&P Waste
- GREEN TEXT – Site disposes 1% to 10% E&P Waste
- BLUE TEXT – Site disposes no E&P Waste (Control)
- The lower the rank value – the higher the average concentration of that parameter
Site Overall Ranking

% E&P Waste as Total of Site Tonnage vs. Avg. Rank Value of All Leachate Parameters

INCREASING % OF E&P WASTE

DECREASING PARAMETER CONCENTRATION
## Leachate Concentration Ranges

<table>
<thead>
<tr>
<th>Leachate Parameter</th>
<th>Landfill A-J Conc. (mg/l) (10%-65% E&amp;P)</th>
<th>Landfills K-N Conc. (mg/l) (2%-10% E&amp;P)</th>
<th>Landfill O-S Conc. (mg/l) (No E&amp;P)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ba</td>
<td>0.5 – 9.0</td>
<td>0.4 – 2.2</td>
<td>0.2 – 0.9</td>
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<tr>
<td>K</td>
<td>137 – 1,080</td>
<td>176 – 1,618</td>
<td>115 – 476</td>
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<tr>
<td>Na</td>
<td>506 – 4,055</td>
<td>639 – 2,538</td>
<td>475 – 1,656</td>
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<tr>
<td>V</td>
<td>0.01 – 0.22</td>
<td>0.01 – 2.42</td>
<td>0.01 – 0.04</td>
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<tr>
<td>Chlorides</td>
<td>939 – 9,835</td>
<td>753 – 2,913</td>
<td>630 – 1,588</td>
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<tr>
<td>Sulfates</td>
<td>30 – 4,848</td>
<td>5 – 1,618</td>
<td>18 -187</td>
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<tr>
<td>TDS</td>
<td>2,832 – 21,433</td>
<td>2,337 – 10,951</td>
<td>2,547 – 6,152</td>
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</table>

### Inter-Site Comparison Conclusions

- In general – landfills disposing higher % and/or tonnages of E&P waste have higher concentrations of select parameters.
Leachate Concentration Ranges

- Chlorides, K, Na, Sulfate & TDS
- Ba & V Concentration (mg/l)

- Landfills A-J (10% - 65%)
- Landfills K-N (2% - 10%)
- Landfills O-S (No E&P)
Impacts on Leachate Composition

► Intra-Site Comparison

• For each site and each parameter
  
  ➢ Separated leachate data into pre-E&P waste acceptance and post-E&P waste acceptance

  ➢ Analyzed for statistical significance of differences of average concentrations

  ➢ Performed t-Test, assuming 2-sample unequal variance, 95% confidence

  ➢ Prepared time series plots
## Impacts on Leachate Composition

- **Pre-E&P vs Post E&P, t-Test Significance**

<table>
<thead>
<tr>
<th>Landfill</th>
<th>Ba</th>
<th>K</th>
<th>Na</th>
<th>V</th>
<th>Chlo.</th>
<th>Sulf.</th>
<th>TDS</th>
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<td>5</td>
<td>8</td>
<td>2</td>
<td>9</td>
<td>1</td>
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</table>

- “Yes” indicates Post-E&P Avg. Concentration is Statistically Significantly Higher than Pre-E&P Avg. Concentration
Impacts on Leachate Composition

Landfill G (65% Avg. Annual E&P Waste)

Parameter Concentration (mg/l)

Date

Start Accepting E&P Waste

- Chlorides - Pre E&P Wastes
- Chlorides - Post E&P Wastes
- TDS - Pre E&P Wastes
- TDS - Post E&P Wastes
Impacts on Leachate Composition

Intra-Site General Conclusions

• Sites disposing moderate to high percentages of E&P wastes over multiple years may experience large increases in concentrations of Na, Chlorides, TDS

• Sites accepting E&P waste may see increases in other metals (Ba, K, V)

• Increases range from minimal to dramatic
What May Be Impacts To Landfills and Leachate from CCR and E&P Wastes?

- **FGD** - Highest hydraulic conductivity and ionic strength values (77 samples) were associated with one specific FGD site with recirculated leachate – mostly low hydraulic conductivity

- **Fly ash leachates** (39 samples) showed low ionic strength gives low predicted GCL hydraulic conductivity values

- **Fly ash/bottom ash leachates** (24 samples) also showed low ionic strength results in low GCL hydraulic conductivity

- **FGD/Fly Ash/Bottom Ash Mixtures.** Facilities with blends of FGD waste and ash (8 samples), showed much lower ionic strengths (<0.13 M) than FGD waste alone

- **MSW** alone had higher ionic strengths – higher clay/GCL conductivity

- **E&P Wastes** in LF – High mono and divalent ions – Na, Cl, Ca,
Considerations for Treatment Design & Operation

► Coal Ash and E&P Waste (some similarities!)
  • Stabilization of wastes prior to disposal
  • Minimize leaching potential of wastes
  • Monofilling
  • Recirculating leachate may exacerbate TDS increases

► Leachate Treatment
  • Need for pretreatment prior to discharge to POTW
  • Impact of increased TDS on settling in SBRs, MBRs may see increased fouling
  • TDS concentrations may not impact nitrification if <5,000 mg/L
  • “Pickling” of bacteria
  • Scale deposition
Conclusions

► Wide range of ionic strengths
► CCR wastes have lower ionic strength than mixed ash in MSW landfills
► Significant variability
► Treatment Considerations –
  ▪ Bench tests recommended because leachate concentrations are highly variable.
  ▪ Chemical precipitation or advanced technologies?
  ▪ Organics not investigated
Questions?

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