Sustainable Management of Coal Combustion Products

Recent EPRI Research

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About EPRI

- Founded in 1973 as an independent, nonprofit center for public interest energy and environmental research.

- Objective, tax-exempt, collaborative electricity research organization.

- Participating companies generate over 90% of North American electricity production.

- Broad technology portfolio ranging from near-term solutions to long-term strategic research.
EPRI’s Role in Technology Development

Help Move Technologies to the Commercialization Stage…

- Basic Research and Development
- Collaborative Technology Development Integration Application
- Technology Commercialization

National Laboratories
Universities
EPRI
Suppliers
Vendors

Technology Accelerator
EPRI Coal Combustion Product Research

- CCP Research Program initiated in 1980 – 30 years of experience and results
- Provides utilities with information and technologies for management of CCPs
- Provides scientific information to inform policy regulatory decisions
  - Technical findings extensively cited in previous two US EPA determinations
- Current focus is to help ensure sustainable CCP management practices combining environmentally sound disposal and increased beneficial use
Presentation Overview

• What are coal combustion products (CCPs)
  – Ash: composition similar to rocks; trace metals slightly enriched
  – FGD gypsum: composition very similar to mined gypsum

• CCP leachates do not exhibit hazardous waste characteristics
  – CCPs do not exceed EPA hazardous waste test limits (TCLP)
  – CCP leachate is similar to non-hazardous inorganic wastes
  – CCP leachate risks several orders of magnitude less than municipal solid waste leachate

• Other Risk Considerations
  – Identified damage cases typically pre-1980, unlined; only 3 off-site exceedances of a Maximum Contaminant Level
  – Mercury in fly ash is not readily released; radioactivity levels are similar to rocks and other building materials
Presentation Overview

- Beneficial use of CCPs yields significant savings in energy, water, and use of natural resources; reduces CO$_2$ emissions
  - 2007 savings: 159 trillion Btu, 32 billion gallons, 11 million tons of CO$_2$e
  - Hazardous waste designation threatens beneficial use

- High management costs threaten electricity capacity margin, reliability
  - Can drive premature plant shut downs
  - Potentially critical in Midwest, Mid-Atlantic, and Texas, and possibly in the Southeast
What are Coal Combustion Products (CCPs)?

**Note**

<table>
<thead>
<tr>
<th>CCP</th>
<th>CCB (Coal Combustion By-Product)</th>
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<tbody>
<tr>
<td></td>
<td>CCR (Coal Combustion Residual)</td>
</tr>
<tr>
<td></td>
<td>CCW (Coal Combustion Waste)</td>
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<td></td>
<td>CUB (Coal Utilization By-Product)</td>
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</table>
Primary Types of Coal Combustion Products

- **Coal Ash**
  - Fly Ash
  - Bottom Ash/ Boiler Slag

- **Wet Flue Gas Desulfurization (FGD) Materials**
  - FGD Gypsum
  - Scrubber Sludge

- **Dry FGD Materials**
  - Spray Dryer Absorber Material
  - Duct/Furnace Sorbent Injection Solids
  - Fluidized Bed Combustion Ash
Fly ash and bottom ash make up about 73% of CCPs; Wet FGD solids (gypsum + scrubber sludge) about 22%
Overall Composition of Coal Ash is Similar to Rocks

Trace elements collectively make up less than 1% of the total

Data Sources:
Taylor and Lichte, 1980; USGS, 1992; EPRI, 2009a
Total Composition of Trace Constituents in Fly Ash are Slightly Enriched Compared to Rocks

For most trace constituents, only a small fraction of the total composition is leachable

Data Sources:
USGS, 2008; EPRI, 2009a
Total Composition of Most Trace Constituents in FGD Gypsum Are Within or Below Ranges in Mined Gypsum

FGD gypsum is relatively pure calcium sulfate

Data Sources:
USGS, 2008; EPRI, 2009a
## Trace Element Composition Summary

<table>
<thead>
<tr>
<th>Material</th>
<th>Fly Ash</th>
<th>Bottom Ash</th>
<th>FGD Gypsum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocks</td>
<td>Enriched</td>
<td>=</td>
<td>≤</td>
</tr>
<tr>
<td>Soils</td>
<td>Enriched</td>
<td>=</td>
<td>≤</td>
</tr>
<tr>
<td>Biosolids</td>
<td>=</td>
<td>=</td>
<td>≤</td>
</tr>
<tr>
<td>Metal Slags</td>
<td>=</td>
<td>=</td>
<td>≤</td>
</tr>
<tr>
<td>Fertilizers</td>
<td>=</td>
<td>=</td>
<td>≤</td>
</tr>
</tbody>
</table>

Overall, trace elements in fly ash are slightly enriched compared to geologic materials, similar to other common materials. Trace elements in FGD gypsum are relatively low.
Does CCP Leachate Exhibit Hazardous Waste Characteristics?
Coal Ash Leachate is Below Hazardous Waste Regulatory Limits

TCLP – Toxicity Characteristic Leaching Procedure

<table>
<thead>
<tr>
<th>As</th>
<th>Ba</th>
<th>Cd</th>
<th>Cr</th>
<th>Pb</th>
<th>Hg</th>
<th>Se</th>
<th>Ag</th>
</tr>
</thead>
</table>
| None of 80 fly ash samples from 33 power plants in EPRI database exceeded federal hazardous waste test (TCLP) limits

Data Source: EPRI, 2009a
Coal Fly Ash Leachate is Similar to Non-hazardous Inorganic Waste Leachate

Ranges for metal slag and foundry sand leachates are similar to fly ash leachate

Data Sources
EPRI, 2009a; Proctor et al, 2000
Leachate Risk Comparison: Coal Fly Ash vs Municipal Solid Waste (MSW)

- MSW regulated as non-hazardous waste (Subtitle D) under Resource Conservation and Recovery Act
- Assessment based on field leachates and risk-based tapwater screening levels
- Comparative risk, not absolute
- Cumulative risk-based screening
  - Human health risk
    - cancer
    - noncancer
  - Ecological risk
Comparative Risks for Coal Fly Ash Leachate are Significantly Lower Than for MSW Leachate

More than 1600 MSW landfills and 250 million tons of MSW per year regulated as non-hazardous waste under Subtitle D
Other Risk Considerations
EPA Damage Cases

Total 63 Sites*

- 24 proven, 39 potential
- 9 surface water, 54 groundwater
- 71% on site facilities
- Half landfills, half impoundments

* Does not include 4 oil ash sites
Groundwater Damage Cases Are Typically Old Sites with Limited Exposure Risk

• Old Sites
  – 65% - 90% began operation before 1980
  – No proven cases lined; 18% of potential cases lined
    • EPA/DOE (2006): 98% of new sites lined

• Low Toxicity Constituents
  – Exceedances mostly sulfate, manganese, boron
  – Only 3 sites (5%) ➔ off-site exceedances of a maximum contaminant level (MCL) in groundwater

• Limited Exposure Risk
  – Only ~ 1/3 sites had potential for groundwater receptors
  – Remediation in progress at 22 of 24 proven damage cases
    (No information on other two)
2007 EPA Draft Screening Level Risk Assessment for CCP Disposal Sites

- EPA estimate of potential arsenic risk
  - 245 sites; landfills and ponds; with and without liners
  - Conservative inputs
  - Modeled risks as high as $2 \times 10^{-2}$

- EPRI estimate of affected population at the 245 sites
  - 85 with potential for downgradient receptors
  - 8,800 dwellings
  - 23,000 individuals

Risk levels equate to 1 additional person in the US expected to develop cancer over a 70-year lifetime (50th percentile)
Other Potential Risk Issues Addressed by EPRI Research

**Mercury**
- Low concentrations, usually less than 1 mg/kg
- Very stable in fly ash at ambient temperatures
- No significant risk to public from beneficial use in wallboard, concrete, or fills

**Radioactivity**
- Not significantly enriched in ash relative to soil or rocks, or conventional concrete or building materials (USGS, 1997)
- For ash storage site worker, exposure from fly ash is about 2% of background radiation exposure

**Windblown Ash**
- Easily controlled with wetting and cover materials
- Power plant worker exposure not above health criteria, public exposure significantly less
What Are Some of the Environmental and Economic Implications of Hazardous Waste Regulation?
CCP Use Has Several Important Environmental Benefits

- Energy Savings
- Water Savings
- Reduced CO₂ Emissions
- Reduced Need for Disposal Sites
- Conservation of Natural Resources

Benefits for major uses were quantified using standard life cycle analysis tools.

States, CCP marketers, trade groups, utilities, and other organizations assert that hazardous waste designation will reduce or eliminate beneficial reuse options.
### Annual Benefits That May Be Lost if CCPs Are Designated a Hazardous Waste

<table>
<thead>
<tr>
<th>Point of Impact</th>
<th>Annual Savings*</th>
<th>Equivalent to</th>
</tr>
</thead>
</table>
| Energy (trillion Btu) | 159 | • Annual energy use for 1.7 million households  
| | | • 47% of annual wind power generation in the U.S. |
| Water (billion gal) | 32 | • 31% of domestic water withdrawals of California in 2000 |
| CO₂ equiv. (million tons) | 11 | • Removal of 1.9 million cars from roadways |
| Land Space (million yds³) | 51 | • More land area than Central Park in New York |
| Financial (billion $) | 5.1-9.7 | • Annual full-time salary of 130,000–240,000 average Americans |

*Based on 2007 data for beneficial use of CCPs.*
Beneficial Use Can Be Encouraged While Managing CCP Risk: Wisconsin Example

Background
- 11 sites on the damage case list, more than any other state
- Instituted non-hazardous regulation in 1988 and beneficial use regulation in 1997
- Now all active sites have liners and groundwater monitoring

Result
- Virtually eliminated groundwater issues
- Beneficial use increased dramatically

Data courtesy of We Energies
High CCP Management Costs May Impact Generating Capacity, Grid Reliability

Costs of hazardous waste disposal and converting from wet to dry management may cause some units to shut down
Reliability Regions Modeled

Economic impact was modeled on a unit by unit basis

Regions based on North American Electric Reliability Corp (NERC), Independent System Operator (ISO), and Regional Transmission Organization (RTO) reliability regions
Modeling Results Indicate Potential Reliability Impacts in Several Regions

<table>
<thead>
<tr>
<th>Region</th>
<th>Summer Generating Capacity (MW)</th>
<th>Coal-Fired Capacity (MW)</th>
<th>Percent of All Megawatts at Risk*</th>
</tr>
</thead>
<tbody>
<tr>
<td>MISO</td>
<td>141,400</td>
<td>67,213</td>
<td>7 – 19 %</td>
</tr>
<tr>
<td>PJM</td>
<td>165,200</td>
<td>65,678</td>
<td>9 – 23%</td>
</tr>
<tr>
<td>ERCOT</td>
<td>72,500</td>
<td>18,620</td>
<td>7 – 12 %</td>
</tr>
<tr>
<td>ISO-NE</td>
<td>33,700</td>
<td>2,650</td>
<td>0 – 3 %</td>
</tr>
<tr>
<td>NY-ISO</td>
<td>39,150</td>
<td>2,641</td>
<td>0 – 3 %</td>
</tr>
<tr>
<td>CAISO</td>
<td>58,100</td>
<td>0</td>
<td>0 %</td>
</tr>
<tr>
<td>SERC</td>
<td>235,500</td>
<td>91,700</td>
<td>Being evaluated</td>
</tr>
</tbody>
</table>

*NERC summer 2017 reference margins for these regions range from 11.1% to 13%

For MISO, PJM and ERCOT, reductions in summer capacity at the low end of the range would put all three regions at or below NERC reference margin levels; SERC is currently being evaluated.
Summary: Weighing the Benefits and the Risks
Summary

• Total Composition
  – Ash composition similar to rocks; trace metals slightly enriched
  – FGD gypsum composition very similar to mined gypsum

• Leaching
  – CCP leachate does not exceed hazardous waste limits (TCLP)
  – Ash leachate similar to non-hazardous inorganic wastes
  – Risk associated with CCP leachate several orders of magnitude less than municipal solid waste (non-hazardous)

• Proven/potential damage cases typically old, unlined
  – most pre-1980; only 3 off-site exceedances of an MCL

• Mercury and radioactivity levels in CCPs present little risk in disposal or use
Summary

• Beneficial use of CCPs yields significant savings in energy and water, and reduces CO2 emissions
  – 2007 savings: 159 trillion Btu, 32 billion gallons, 11 million tons of CO2e, 51 million cubic yards in land space
  – Hazardous waste designation threatens beneficial use

• High CCP management costs threaten electricity capacity margin, reliability
  – Potentially critical Midwest, Mid-Atlantic, and Texas
  – Likely important in Southeast
Together…Shaping the Future of Electricity

www.epri.com/ccp
References


References (continued)


