Mercury Emission Controls and Clean Coal

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Outline

• Coal and energy generation
• Environmental and health issues
• Brief history of mercury regulations
• Overview of mercury capture at coal fired power plants
• Coal and Green Chemistry
Why Do We Use It?

- Electricity generation
  - 93% domestic and imported coal
  - Nearly half of electricity
- Most abundant fossil fuel
  - 260 billion tons recoverable in US
  - 929 billion tons recoverable in world
- Cheap (2008)
  - Coal: $1.61/mil BTU
  - Natural Gas: $7.31/mil BTU
  - Oil: $16.21/mil BTU
- Domestic
SO$_{x}$/NO$_{x}$/PM

- Acid rain ($SO_{x}$/NO$_{x}$) affects
  - Water
  - Plants
  - Buildings/structures
- NO$_{x}$ cause
  - Smog formation
  - Irritation
- PM is
  - Dirty
  - Irritating
  - Unhealthy

http://interestingenergyfacts.blogspot.com/2008/03/coal-facts.html
Mercury and Human Health

- US human exposure primarily through eating fish
  - Bioaccumulation
  - Fetuses and children at most risk
  - Neurological problems
    - Numbness, weakness, vision and hearing loss, tremor, death
  - Possible kidney, heart, and immune system problems with chronic exposure

US Mercury Regulations

- **Clean Air Act Amendments of 1990**
  - 1998: Hg identified as HAP by EPA
  - By 2000 EPA was to set emission standards
  - By 2007 enforcement of standards was to begin

- **Clean Air Mercury Rule (2005)**
  - By 2018, emissions 15 tons/year (down from 40)
  - Immediate action by states, environmental groups, Native American Tribes
  - Bush administration officials pushed CAMR

- **CAMR overturned in 2008**

- **MACT standards within 2 years**
Hg$^{2+}$ Removal

- Water soluble
- Easily removed using wet flue gas desulfurization

Hg($p$) Removal

- Easily removed with fly ash particles in electrostatic precipitators or bag houses

Hg$^0$ Removal

- Not water soluble
- Oxidation to Hg$^{2+}$ ($\text{HgCl}_2$)
  - $2 \text{Hg} + 4 \text{HCl} + \text{O}_2 \rightarrow 2 \text{HgCl}_2 + 2 \text{H}_2\text{O}$
Selective Catalytic Reduction Catalysts

- Used to remove NO\textsubscript{x} from flue gas
- V\textsubscript{2}O\textsubscript{5} on TiO\textsubscript{2}

Mercury Specific Oxidation Catalysts

- Au, Pt, Pd
  - Longer catalyst life
  - Cost?
- Fe\textsubscript{2}O\textsubscript{3}
  - Deactivates easily
  - Variable performance
Langmuir-Hinshelwood

A \ (g) \leftrightarrow A \ (ads)
B \ (g) \leftrightarrow B \ (ads)
A \ (ads) + B \ (ads) \rightarrow C \ (ads)
AB \ (ads) \rightarrow C \ (g)

http://www.techem.ruhr-uni-bochum.de/muhler/ger/Mikrokinetik.html
Eley-Rideal

\[ A \ (g) \leftrightarrow A \ (ads) \]

\[ A \ (ads) + B \ (g) \rightarrow C \ (g) \]
Activated Carbon

- Variable performance (25-95%)
- Fly ash can also be used
- Large C:Hg needed for 90% removal (3000-18,000:1)
- Unknown mechanism
- Cost
Greenidge Multi-Pollutant Control

- PPII
- 161 MW plant in NY
- $32,742,976
  - DOE: $14,341,423
- 2006-2008
- Reduces Hg by 95%
- Hg removal adds no cost
Presque Isle Power Plant

- DOE CCPI
- 3 – 90 MW boilers
- $52,978,115
  - DOE: $24,859,578
- O&M cost
  - $0.81/MWh
- $16,000/lb Hg removed
- 90% Hg removal
Lies My Lobbyist Told Me

Power plant emissions controls are looking good!
What About…?

[Image of a warning sign: Warning - Danger Underground Mine Fire. Walking or driving in this area could result in serious injury or death. Dangerous gases are present. Ground is prone to sudden collapse.]

[Image of a mining site with a large open-pit mine and trees in the background.]

[Image of a medical symbol with a caduceus and snakes.]


[Image of a web address: http://www.istockphoto.com/]


[Image of a web address: http://www.depweb.state.pa.us/abandonedminerec/cwp/view.asp?q=457768]
2004 Coal Utilization By-products

- 122 million tons CUB created
- Some recycled
- 60% sent to landfills

CUB samples, clockwise from upper left: fly ash, bottom ash, FGD material, and boiler slag.
Tennessee 2008

http://feww.wordpress.com/2008/12/25/
# Clean Coal and Green Chemistry

<table>
<thead>
<tr>
<th>Mercury Emission Controls</th>
<th>Coal as a Whole</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Cleaning up instead of preventing waste</td>
<td>• Coal is not renewable</td>
</tr>
<tr>
<td>• Near 100% capture is possible</td>
<td>• Mining effects</td>
</tr>
<tr>
<td>• Lots of materials are needed to clean emissions</td>
<td>• Lots of energy is expended mining</td>
</tr>
<tr>
<td>• Prevents mercury poisoning</td>
<td>• CUBs not fully reusable</td>
</tr>
<tr>
<td></td>
<td>• Power plant waste is dangerous</td>
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</tbody>
</table>
Take-home Message

- Coal *is* abundant and not going away.
- A lot of time, resources, and money are going into cleaning up emissions (and creating ad campaigns!).
- Coal mining is still dirty and dangerous.
- CUB storage and reuse need improvement!
- Is it all worth it for the short-term? For the long-term?
References


References (cont…)


THANK YOU!
What Is Coal?

- Plant matter compressed over millions of years
- Contains Hg, As, Cd, Cr, Pb, and many other metals
- Hundreds of organic and inorganic compounds
## Types of Coal

<table>
<thead>
<tr>
<th>Type</th>
<th>Energy (millions J/kg)</th>
<th>Carbon Content</th>
<th>Mercury Content (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anthracite</td>
<td>30-34</td>
<td>86-97%</td>
<td>Low</td>
</tr>
<tr>
<td>Bituminous</td>
<td>23-34</td>
<td>45-86%</td>
<td>0.036-0.128</td>
</tr>
<tr>
<td>Subbituminous</td>
<td>16-23</td>
<td>35-45%</td>
<td>0.055-0.069</td>
</tr>
<tr>
<td>Lignite</td>
<td>13-16</td>
<td>25-35%</td>
<td>0.087-0.116</td>
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</tbody>
</table>
• About half of US coal is strip mined
• Underground mines

http://www.teachcoal.org/aboutcoal/articles/coalreserves.html
NETL/DOE Funding

- **Clean Coal Technology Demonstration Program (1985) and Clean Coal Power Initiative (2001)**
  - Spur commercialization of pollution prevention technology
  - Over $5 billion

  - Retrofit existing power plants with new technology
  - $72 million
Humans and wildlife affected primarily by eating fish containing mercury. Best documented impacts are on the developing fetus: impaired motor and cognitive skills.

Mercury transforms into methylmercury in soils and water, then can bioaccumulate in fish.
Mercury (2005)

http://www.chem.unep.ch/Mercury/Atmospheric_Emissions/UNEP%20SUMMARY%20REPORT%20CORRECTED%20May09%20final%20for%20WEB%202008.pdf

Mercury emissions, tonnes

Dental amalgam (cremation)
Waste incineration, waste and other
Chlor-alkali industry
Cement production
Artisanal and small-scale gold production
Large-scale gold production
Metal production (ferrous and non-ferrous)
Fossil fuel combustion for power and heating
Wet FGD System

Mercury Capture and Fate Using Wet FGD at Coal-Fired Power Plants. US DOE, NETL. August 2006.