2016 Fall Forum: Health and the Environment in North Carolina

Environmental Health Scholars Program
Coal Ash Session

8:30 - 8:50: **Overview on Coal Ash Risks** – *Avner Vengosh*, Nicholas School of the Environment, Duke University
9:30 - 9:50: **Coal Ash Ponds: Could They Contribute to Alzheimer’s Disease Risk in Residential Populations?** - *Julia Kravchenko*, Duke University Medical Center

9:50- 10:10: **Break**

11:00 - 11:30: **Protecting Clean Water in North Carolina** – *Nick Torrey*, Southern Environmental Law Center
11:00 - 11:30: **Coal Ash Regulation in the U.S.: the National Perspective** - *Lisa Evans*, Earthjustice
11:30 - 12:00: **Discussion**
Overview on Coal Ash Risks

Avner Vengosh
The Energy-Water Quality Nexus Research at Duke

Mountaintop coal mining

Coal ash disposal/spills

Shale gas and hydraulic fracturing

Tar sand, Oil shale
Risks of Coal Ash to the Environment and Human Health

Avner Vengosh, Helen Hsu-Kim (Pratt School of Engineering),

PhD students

- Laura Ruhl*,
- Jennie Harkness,
- Nancy Lauer,
- Grace Schwartz,
- Amrika Deonarine.

*University of Arkansas at Little Rock
Coal is a major energy source in the US – also in the future

Figure 13. Electricity generation by fuel, 1990-2040 (trillion kilowatthours)
Formation of coal combustion residues (CCRs)

Coal combustion

Coal ash residues
Five hundreds power plants nationwide generate approximately 130 million tons of coal ash each year.
Disposal of Coal Combustion Residuals

- Coal ash ponds, Impoundments (22%)
- Landfills (34%)
- Cement industry, beneficial use (37%)

* Based on EPA data
Environmental Risks of coal ash

- Coal ash ponds
  - Spills
  - Groundwater
  - Leaks (Surface water)

- Landfills
  - Leaks
  - Groundwater
  - Airborne particles (PM2.5)
Potential exposure to coal ash contaminants

contaminated drinking water

Coal ash ponds

Coal ash particles

inhalation

Storage, landfills
The contaminants cycle: From fossil swamps to modern waterways

- Combustion
- Volatilization
- Retention of contaminants onto fly ash (scrubbers)
- Storage of coal ash in ponds
- leaching
- Contamination of water resources

Contaminants: As, B, Se, Sr, Ra
Pollutants from coal ash that could be released to the environment.
Due to the attachment of elements to the surface of coal ash → they are easily mobilized to water → causing water contamination
Developing isotopic tracers to characterize coal ash geochemical fingerprints
Boron isotope ratios in coal and coal ash

Ruhl et al. (ES&T, 2014)
# Evidence for Environmental Impact of Coal Combustion Residues

<table>
<thead>
<tr>
<th>Spills</th>
<th>Outfalls</th>
<th>Leaks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tennessee Valley Authority (TVA) spill, Kingston TN, 2008; Dan River spill, Eden, NC, 2014</td>
<td>Discharge of effluents and contamination of NC waterways</td>
<td>Leaking of coal ash ponds in Southeast U.S., evidence for water contamination</td>
</tr>
</tbody>
</table>

- Ruhl et al., (2009, 2010)
- Ruhl et al., (2012)
- Harkness et al., (2016)
In U.S. effluents from coal ash ponds are discharge from “regulated” outfalls.
A study on impact of the discharge from coal ash ponds on surface waters in North Carolina
High arsenic concentrations in some of the effluents from coal combustion residues ponds

Effluents from coal ash ponds

- Dan River
- French Broad River
- Hyco Lake
- Jordan Lake
- Lake Norman
- Wylie Lake
- Mayo Island
- Belews Lake
- Julian Lake

NC WS stds and EPA MCL

Outfall

Hyco Lake
Enrichment factors of coal ash pond effluents relative to upstream waters

Two- to three-orders of magnitude of contaminants enrichment: evidence for high contaminants levels in coal ash effluents

Figure 2: Mean values of enrichment factors of dissolved constituents in CCR effluents disposed from plants with an FGD system (red) and without an FGD system (blue). The enrichment factors were calculated by the ratio of different elements concentrations in directly sampled CCR effluents to the concentrations in the upstream water that feeds each plant.
Redox-sensitive contaminants are enriched in deep water associated with lake thermal stratification.
Recycling of arsenic: long-term accumulation in lake sediments: under anoxic conditions $\rightarrow$ release of As to porewater
Hot spot: Porewater Concentrations
## Arsenic as As (III)

<table>
<thead>
<tr>
<th>Date Sampled</th>
<th>Body of Water</th>
<th>Sample</th>
<th>Total As</th>
<th>% as As(III)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug-11</td>
<td>Hyco Lake</td>
<td>Lake</td>
<td>14.9</td>
<td>82</td>
</tr>
<tr>
<td>Aug-11</td>
<td>Hyco Lake</td>
<td>Outfall</td>
<td>83.3</td>
<td>82</td>
</tr>
<tr>
<td>Aug-11</td>
<td>Hyco Lake</td>
<td>Lake</td>
<td>59.7</td>
<td>87</td>
</tr>
<tr>
<td>Aug-11</td>
<td>Hyco Lake</td>
<td>Lake</td>
<td>33.4</td>
<td>89</td>
</tr>
<tr>
<td>Sep-10</td>
<td>Mayo Reservoir</td>
<td>Lake</td>
<td>6.4</td>
<td>99</td>
</tr>
<tr>
<td>Sep-10</td>
<td>Mayo Reservoir</td>
<td>Outfall</td>
<td>154.9</td>
<td>88</td>
</tr>
<tr>
<td>Aug-11</td>
<td>Mayo Reservoir</td>
<td>Outfall</td>
<td>29.2</td>
<td>86</td>
</tr>
<tr>
<td>Aug-11</td>
<td>Mayo Reservoir</td>
<td>Lake</td>
<td>4.7</td>
<td>90</td>
</tr>
<tr>
<td>Aug-11</td>
<td>Jordan Lake</td>
<td>Lake</td>
<td>5.1</td>
<td>67</td>
</tr>
<tr>
<td>Aug-11</td>
<td>Jordan Lake</td>
<td>Outfall</td>
<td>3.8</td>
<td>70</td>
</tr>
<tr>
<td>Aug-11</td>
<td>Jordan Lake</td>
<td>Lake</td>
<td>3.3</td>
<td>91</td>
</tr>
</tbody>
</table>
The impact of coal ash ponds on water resources

Clear evidence for leaking of coal ash ponds in North Carolina

Harkness et al. 2016, (ES&T)
Conclusions

- Formation of coal combustion residues are enriched with toxic elements (As, Se, Pb, Ra, B) that are mobilized to generate contaminated effluents that can leaked to the environment.
- The enrichment of contaminants on coal ash is associated with geochemical and isotopic fingerprints that are used to delineate the impact of coal ash in the environment.
- Clear evidence for environmental impacts and contamination of surface water and groundwater from spills (TVA, Dan River), discharge of coal ash ponds effluents, and leaks of coal ash ponds.
Acknowledgements….

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- North Carolina Water Resources Research Institute,
- National Science Foundation,
- and Oak Ridge Association of Universities.

For more information and publications:

http://sites.nicholas.duke.edu/avnervengosh/
Origin of Hexavalent Chromium in Drinking Water Wells from the Piedmont Aquifers of North Carolina

Avner Vengosh,*† Rachel Coyte,‡ Jonathan Karr,* Jennifer S. Harkness,* Andrew J. Kondash,* Laura S. Ruhl,* Rose B. Merola,* and Gary S. Dywer†

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Supporting Information
Occurrence of dissolved chromium in water:

- Trivalent chromium – Cr(III)
- Hexavalent Chromium – Cr(VI)

Distribution of chromium species in water

[Diagram showing the distribution of chromium species in water with labels for hexavalent chromium and trivalent chromium.]
North Carolina Department of Health and human Services

April 2015 - letters to hundreds homeowners living near coal ash ponds

Do not drinking your well water !!!!!!!!!!

High hexavalent chromium and vanadium

(6 months later, another letter, its OK to drink now…..)
Hexavalent chromium is known to be a highly toxic and carcinogen...

<table>
<thead>
<tr>
<th>State / Agency</th>
<th>Threshold</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPA – federal Safe Drinking Water Act</td>
<td>Hexavalent chromium: N/A</td>
</tr>
<tr>
<td></td>
<td>Total chromium: 100 ppb</td>
</tr>
<tr>
<td>NC 02L groundwater standard</td>
<td>Hexavalent chromium: N/A</td>
</tr>
<tr>
<td></td>
<td>Total chromium: 10 ppb</td>
</tr>
<tr>
<td>NC DHHS health screening level</td>
<td>0.07 ppb</td>
</tr>
<tr>
<td>California drinking water standard</td>
<td>10 ppb</td>
</tr>
<tr>
<td>California public health goal</td>
<td>0.02 ppb</td>
</tr>
</tbody>
</table>

Dissolved chromium in water:

- Trivalent chromium – Cr(III)
- Hexavalent Chromium – Cr(VI)
Total chromium distribution in groundwater from the Piedmont aquifers, North Carolina
Hexavalent chromium is the predominant species of dissolved chromium in groundwater.

\[ r^2 = 0.93 \quad (p<0.001; \ n=77) \]

Vengosh et al (2016), *ES&T Letters*
Total chromium distribution in groundwater from the Piedmont aquifers, North Carolina
No correlation with distance to the nearest coal ash pond

$R^2 = -0.003$

$p = 0.8$
The strontium isotopes fingerprint of groundwater with high hexavalent chromium is different from the composition of coal ash effluents.

\[ \frac{\text{Sr}^{87}}{\text{Sr}^{86}} \]

\[ \text{Sr/Ca} \]

Vengosh et al. (2016), *ES&T Letters*
The boron to chromium ratio of groundwater with high hexavalent chromium is different from the ratios in coal ash effluents (Vengosh et al., 2016, *ES&T Letters*).
Coal ash and hexavalent chromium

• The enrichment and mobilization of multiple toxic elements in coal ash pose environmental and human health risks;
• Clear evidence for coal ash effluents leaking to shallow groundwater near coal ash ponds;
• Hexavalent chromium is naturally occurring and derived from water-rock interactions, thus its occurrence in groundwater depends on the aquifer geology, not proximity to coal ash ponds.
• Hexavalent chromium is far more abundant in drinking water wells than previously thought, need specific regulation.