Coal ash and children's neurobehavioral health: An on-going study.

Kristina M. Zierold, PhD, MS
Epidemiology and Population Health
School of Public Health, University of Louisville
Kristina.Zierold@Louisville.edu
(502) 852-0251
What is Coal Ash?

- When coal is burned for energy, coal ash waste products result.

- Geochemical make-up of the coal used and the burning process determines the waste produced:
  - Fly Ash
  - Bottom Ash
  - Boiler Slag
  - Flue gas desulfurization (FGD) gypsum

- Fly Ash is predominate.
Fly Ash

- Fly ash = small (PM10), spherical particles
- Silt-like

- May be comprised of **hazardous** components
  - Some are toxic or radioactive
    - Metals: chromium, lead, mercury, titanium, manganese
    - Radioactive: radium, uranium
    - Others: dioxins, polycyclic-aromatic hydrocarbons (PAHs)
Fly Ash

- Not considered a hazardous waste
- Fly ash is stored in landfills and ponds, usually near residential neighborhoods
- 2015 – Disposal of Coal Combustion Residuals from Electric Utilities Rule
- ~56% coal ash is reused in products like concrete
Health Studies - Very Limited

• Several Occupational (fly ash exposed)
  ▫ Higher levels of arsenic and mercury compared to healthy controls
  ▫ Increased genetic mutations and cell damage
  ▫ Decreased lung function
  ▫ Increased birth defects
  ▫ Neurological outcomes

• Prenatal followed up after birth (before and after plant closure)
  ▫ 1\textsuperscript{st} study found decreased developmental factors (language, motor development, etc.)
  ▫ 2\textsuperscript{nd} study found no decrease
# Fly Ash from Coal Burning

<table>
<thead>
<tr>
<th>Fly Ash Component</th>
<th>Health Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic compounds (Inorganic)</td>
<td>Skin lesions, peripheral neuropathy, cardiovascular problems, associations with skin, lung, and bladder cancers, possible effects to pregnant women and fetuses</td>
</tr>
<tr>
<td>Lead compounds</td>
<td>Damage to nervous system, kidneys, and reproductive system, hypertensive effects, and damage to hearing</td>
</tr>
<tr>
<td>Chromium compounds</td>
<td>Lung cancer, respiratory and gastrointestinal damage, asthma, pneumonia, bronchitis, possible complications in pregnancy and childbirth, anemia</td>
</tr>
<tr>
<td>Mercury compounds</td>
<td>Damage to the nervous system, heart, kidneys, lungs, and immune system. Neurological damage to developing fetus</td>
</tr>
<tr>
<td>Cadmium compounds</td>
<td>Metal fume fever, kidney disease, bronchiolitis, emphysema, anemia, reduction in sperm number, low birthweight, possible other reproductive effects, lung cancer</td>
</tr>
<tr>
<td>Uranium, thorium, radium, radon</td>
<td>Lung cancer, pancreatic cancer, bone cancer, lymphoma, leukemia, aplastic anemia</td>
</tr>
</tbody>
</table>
2012-2014 - Pilot Study with the Community Around One Power Plant

• Mixed-methods study assessing prevalence of health conditions

• Organized 11 community leaders, from 4 neighborhoods near the plant
  ▫ Non-transient, long-term community members
  ▫ Interested in environmental health
  ▫ Helped with questionnaire development, recruitment, planning, etc.

• Findings in short
  ▫ Prevalence of behavioral and emotional conditions (ADHD, learning disabilities, conduct problems) greater than USA

• Example: ADHD = 38.3% exposed, 16% in comparison group 6.8% in US.
Specific Aims of Current NIEHS Grant

• Characterize indoor exposure from fly ash and heavy metals in homes of children residing near coal ash storage sites compared to children living further away from coal ash storage sites.

• Determine if the heavy metal body burden differs from children residing near coal ash storage sites compared to children living further away from storage sites.

• Assess if increased fly ash exposure and greater heavy metal body burden is associated with poorer neurobehavioral performance and more neurobehavioral symptoms.

• Utilize mapping, spatial analysis and modeling applications of geographic information systems (GIS) for household recruitment, analysis of distance decay effects, surface interpolation of Aims 1 and 2 results, and fate and transport modeling of fly ash.
To accomplish the aims...

- Overall, recruit 300 children throughout west and southwest Louisville, over 5 years
  - Aged 6-14
  - Live within 10 miles of the power plants/storage sites
  - “Shoe-Leather” methods
  - Mailings to neighborhoods
  - Stores/schools/other
As of Sept 2017

Each buffer is two miles.

Study outlier

Season
- Fall
- Spring
- Summer
- Winter
Exposure Assessment

- Air Sampling – in home
  - PM$_{10}$ (PIXE)
  - Fly Ash (SEM/EDX)

- Lift Sampling for fly ash (SEM/EDX)

- Collection of nail samples for metals analysis (PIXE)
Outcome Measures

- **BARS**
  - Behavior Assessment Research System
    - Series of computer tests that measure performance
      - Attention, memory, fine motor skills, response speed

- **Purdue pegboard, Beery VMI, Object Memory**

- **Child Behavior Checklist**
  - Evaluated as continuous
  - Evaluated as dichotomous (borderline/clinical vs. not)
## Test Used and Measurement

<table>
<thead>
<tr>
<th>Neurobehavioral Test</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Finger tapping</td>
<td>Response speed and coordination</td>
</tr>
<tr>
<td>Symbol digit</td>
<td>Coding/Information processing speed</td>
</tr>
<tr>
<td>Match to Sample</td>
<td>Visual memory</td>
</tr>
<tr>
<td>Digit Span</td>
<td>Memory and attention</td>
</tr>
<tr>
<td>Continuous Performance</td>
<td>Sustained attention</td>
</tr>
<tr>
<td>Beery VMI</td>
<td>Hand-eye coordination</td>
</tr>
<tr>
<td>Object Memory</td>
<td>Recall and recognition memory</td>
</tr>
<tr>
<td>Perdue Pegboard</td>
<td>Dexterity</td>
</tr>
</tbody>
</table>
Additional Items Used

- **Questionnaires**
  - **Environmental Health History**
    - 108 multiple choice/Likert scale
    - Developed based on other pediatric environmental exposure history guides
  - **Home Cleaning**
    - 9 multiple choice

- **Activity Diary**
  - Filled out by participant during the sampling week

- **Pediatric Health History**

- **Home Exposure Assessment**
  - Pediatric Environmental Home Assessment form
Role of Community Leaders

• Be recognized as leaders in their neighborhoods
  ▫ Answer questions from neighbors
  ▫ Explain and support study

• Help recruit
  ▫ Identify other avenues for recruitment

• Provide feedback on study methods, recruitment methods

• Community members as citizen scientists also important
  ▫ Snowball sampling
To date..

• Have consented/assented 162 children and one of their parents
  ▫ 46% of homes have had fly ash on their filters
  ▫ 62% of homes have had fly ash on their lift tape sample

• Most common metals/metalloids found in PM10
  ▫ Aluminum, Titanium, Silicon, Arsenic, Manganese, Chromium

• Most common metals/metalloids in fly ash
  ▫ Aluminum, Iron, Silicon, Potassium, Titanium
What’s going on with the data?

- Preliminary Results - 2 PhD dissertations, 2 MS theses
  - The particulars about particulates: Exposure to metals and self-regulation of children living near coal ash storage
  - Pediatric anxiety and/or depression problems: Associations with PM10, fly ash, and metal exposure
  - Coal ash exposure and neurobehavioral performance
  - Coal ash exposure and childhood asthma

- 9 abstracts presented of preliminary findings

- Some patterns in data
  - Elevated Odds Ratios
  - Aluminum, copper, manganese relationships

- Findings will be better understood after the entire sample is recruited in 2020.
Acknowledgements

- NIH/NIEHS (R01ES024757)
- Co-Investigators
  - Lonnie Sears, PhD
  - Carol Hanchette, PhD
  - Barbara Polivka, PhD
  - Guy Brock, PhD
- Current and Previous Students
  - Clara Sears, MS, PhD
  - Abby Burns, MPH, PhD
  - Lindsay Tompkins, MS, Doctoral Student
  - Chisom Odoh, MPH, Doctoral Student
  - Jack Pfeiffer, MS, Doctoral Student
- Other Students for current project and pilot project
- Community Leaders
- Community Participants

Much more to come, when the study is done...