Prevention of Health Effects in Children from Energy-Related Air Pollution

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Prevention of Health Effects in Children from Energy-Related Air Pollution

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Chongqing University of Medical Sciences (CQUMS)

Tongliang County Hospital, Chinese Medicine Hospital and Maternal Children Hospital

Columbia University’s Center for International Earth Science Information Network (CIESIN)

Chongqing Institute of Environmental Sciences (CQIES)
Introduction

- Air pollution from burning of coal can cause serious illness ranging from respiratory problems to cancer and developmental disorders in children.

- There is evidence that the fetus and young child are inherently more sensitive than adults to the toxic effects of air pollution.

- In addition to the intangible costs of human suffering, air pollution imposes major financial costs on society in terms of health care alone.

- There is an urgent need for prevention.
Columbia Center for Children’s Environmental Health

Poland
- Growth & Development
- Asthma
- Cancer Risk
- Cohort

New York City
- Growth & Development
- Asthma
- Cancer Risk
- Cohorts

China
- Growth & Development
- Asthma
- Cancer Risk
- Serial Birth Cohorts
- Environmental Intervention
- Policy

WTC Cohort
Hypotheses

Prenatal Environmental Exposures Is Associated With Adverse Effects of Child Health

Exposures: Combustion related air pollutants, polycyclic aromatic hydrocarbons (PAHs), particulate matter (PM$_{2.5}$), heavy metals

Biomarkers: PAH-DNA adducts, PAH metabolites, and DNA methylation, heavy metals, gene polymorphisms

Child development, Asthma and Cancer Risk
Biomarkers of Exposure Assessment

Black Box

Molecular Epidemiology

Exposure → Black Box → Clinical Disease
Polycyclic aromatic hydrocarbons (PAH), especially benzo(a)pyrene (BP) as a representative member of this class of hydrocarbons, are an important class of carcinogens that are widespread in the ambient environment due to incomplete fossil fuel combustion for energy production, transportation and industry. PAH are also found in tobacco smoke and foods such as charred and broiled meat.
Benzo[a]pyrene

Glutathione (GSTs)

CYP1A1

BP-7,8-epoxide

Reductase

BP-7,8-diol 9,10-epoxide

Glucuronide

EH

BP-7,8-dihydrodiol

Sulfate esters

CYP3A4

Tetrol, Triol

GSTs

BP-7,8-diol 9,10-epoxide

Guanine

Repair

BPDE-DNA Adduct

Mutation

CANCER
Benzo[a]pyrene (PAH)-DNA Adduct

- **Phosphate Group**
- **Benzo[a]pyrene**
- **DNA Backbone**
- **Nitrogen Base Pair**
- **Yellow - Phosph.**
- **Red - Oxygen**
- **Blue - Nitrogen**
- **White - Carbon**
PAH DNA Adducts - An Integrated Biological Dosimeter of PAH Exposure

*Multiple exposure routes
*Abortion, metabolic rate
*Susceptibility factors

Exposure

Biological Exposure Assessment

Exposure

Molecular Epidemiology

Clinical Disease

Internal Dose → Biologically effective dose → Preclinical effect

Markers of Susceptibility
Study Site Selection

Image provided by Columbia University’s Center for International Earth Science Information Network (CIESIN)

Tongliang, Beijing, Shanghai
Generator (46,000 kW)
Fuel: Coal (24,000T/yr)
Coal: S=2-5%, Ash=30%
Operation: Dec.-June
Emission:
SO₂: 2500-4000 mg/m³
(1800mg/m³)
Particles: 2000mg/m³
(250mg/m³)

TongLiang Power Plant

Image provided by Columbia University's Center for International Earth Science Information Network (CIESIN)
Mother/Newborn Study Design

Cohort I
3/02-6/02
150 pairs

Cohort II
3/05-6/05
150 pairs

Cohort III
3/07-6/07
150 pairs

5/2004

Comparing before and after:
1. Air monitoring data
2. Biomarker data
3. Fetal/Child growth and development
4. Respiratory illness
Ambient Air Monitoring

University of Nevada, Desert Research Institute (DRI)
Chongqing Institute of Environmental Sciences (CQIES)
Harvard University, Department of Environmental Health

Image provided by Columbia University’s Center for International Earth Science Information Network (CIESIN)
Results of Air Monitoring for the Period from March 2002-Feb 2003

The average PM$_{2.5}$ values (115.4 µg/m$^3$) are 7-8 times higher than the annual PM$_{2.5}$ U.S. National Ambient Air Quality Standard (NAAQS) of 15 µg/m$^3$

Average benzo(a)pyrene (BaP) (a PAH) levels (13.23 ng/m$^3$) are about two orders of magnitude higher than BaP levels (0.03-0.1 ng/m$^3$) in Southern California or NYC (0.5 ng/m$^3$)

Elevated benzonaphthothiophene (sulfur PAH) indicates contribution from coal combustion

Chow et al., 2006 *J Environ Sci Health A Tox Hazard Subst Environ Eng.*
### Table 2. Association between cord blood PAH-DNA adducts (dichotomized high/low) and birth outcomes/physical growth.

<table>
<thead>
<tr>
<th></th>
<th>Birth</th>
<th>18 months</th>
<th>24 months</th>
<th>30 months</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β (n)</td>
<td>p-Value</td>
<td>β (n)</td>
<td>p-Value</td>
</tr>
<tr>
<td>Weight</td>
<td>-0.007 (112)</td>
<td>0.738</td>
<td>-0.048 (110)</td>
<td>0.03</td>
</tr>
<tr>
<td>Length or height</td>
<td>-0.001 (112)</td>
<td>0.89</td>
<td>-0.005 (110)</td>
<td>0.483</td>
</tr>
<tr>
<td>Head circumference</td>
<td>-0.011 (112)</td>
<td>0.057</td>
<td>-0.012 (109)</td>
<td>0.085</td>
</tr>
</tbody>
</table>

*Models included ETS, sex, maternal height, and maternal weight as covariates. Gestational age was additionally considered as a covariate for birth outcome analysis, and maternal head circumference and cesarean status were additionally considered as covariates for all analyses involving head circumference.

Tang et al., *Environmental Health Perspectives*
Volume 114, Number 8, August 2006 1297-300
Child Cognitive Development (Gesell Scores) at Age 2 and PAH-DNA Adducts adjusting for Lead in Cord Blood (2002 cohort, N=88 Detectable Adducts only)

<table>
<thead>
<tr>
<th>Motor</th>
<th>Adaptive</th>
<th>Language</th>
<th>Social</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>β</td>
<td>p-value</td>
<td>β</td>
<td>p-value</td>
<td>β</td>
</tr>
</tbody>
</table>

Analysis was based on 88 detectable cord adducts adjusting for gender, gestational age, blood lead level and maternal education level.
Mother/Newborn Study Design

Cohort I
3/02-6/02
150 pairs

Cohort II
3/05-6/05
150 pairs

Cohort III
3/07-6/07
150 pairs

5/2004

Downtown, Tongliang City
The Air PAHs Levels of Tongliang

2002-3  2005-6
The PAH-DNA adducts level of newborns was 22% lower (p<0.001) after power plant shut down. The analysis is adjusted for ETS during pregnancy.
### Measures of Fetal Growth

<table>
<thead>
<tr>
<th>Measure</th>
<th>2002</th>
<th>2005</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight (g)</td>
<td>3337.5 ± 388.1 (149)</td>
<td>3406.0 ± 399.8 (158)</td>
</tr>
<tr>
<td>Length (cm)</td>
<td>50.34 ± 1.7 (149)</td>
<td>50.30 ± 1.5 (155)</td>
</tr>
<tr>
<td>Head Circumference (cm)&lt;sup&gt;a&lt;/sup&gt;</td>
<td>33.8 ± 1.1 (149)</td>
<td>34.2 ± 1.3 (157)&lt;sup&gt;*&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

*Adjusting for gender, gestational age, maternal head circumference, and caesarian status *p=0.069
Gesell scores in the two prospective cohorts on development Delay (%)
2005 Cohort: No Association between Cord PAH-DNA Adduct Level and Birth Outcomes

(2006 Cohort Collected after Power Plant Shut Down)

<table>
<thead>
<tr>
<th></th>
<th>Continuous</th>
<th>High-low</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β</td>
<td>p-value</td>
</tr>
<tr>
<td>Weight</td>
<td>-0.135</td>
<td>0.378</td>
</tr>
<tr>
<td>Length</td>
<td>0.048</td>
<td>0.250</td>
</tr>
<tr>
<td>HC</td>
<td>0.011</td>
<td>0.795</td>
</tr>
</tbody>
</table>

Models included ETS, gender, maternal height, and maternal weight as covariates. Gestational age was additionally considered as a covariate for birth outcome analysis, and maternal head circumference and cesarean status were additionally considered as covariates for all analyses involving head circumference.
Summary

PAH DNA adducts is a good integrated biological dosimeter of PAH exposure.

The air concentration of PAHs in Tongliang were significantly higher before the power plant shut down.

PAH-DNA adduct levels were significantly reduced after the power plant shut down.

Birth outcomes were improved after the power plant shut down.
Better Policy
Cleaner Environment
Healthier Children

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