Exposure Assessment using Biomonitoring

June 29, 2004
Biomonitoring

assessment of internal dose exposure by measuring a toxicant (or its metabolite) in human specimens such as blood, urine, saliva, or adipose
Exposure and health effects pathway

**External dose:** air, water, food, soil, dust

inhalation

ingestion

skin absorption

**Internal dose:** blood, serum, urine, tissue

Health effect
Choice of matrix and form of chemical

- Parent chemical in serum, urine, saliva
- Metabolite in serum, urine, saliva
- Protein adduct (albumin or hemoglobin) in serum or whole blood

Note the different exposure time frames represented by each of these measurements
Persistent toxicant in blood and urine

- Blood/serum level
- Hemoglobin adduct
- Albumin adduct
- Urinary metabolite

Concentration vs. Time (Days)
Non-persistent toxicant in blood and urine

Blood/serum level

Urinary metabolite

Albumin adduct

Hemoglobin adduct

Concentration

Time (Days)
Biomonitoring measurements can **CALIBRATE** and **VALIDATE** an exposure index based on other information.

The exposure index can then be applied to many people including persons who have died.
Couple the right epidemiologic design to the appropriate biomonitoring measurement to answer the public health question of interest

Case control studies

Nested case control studies

Assessment of 20-30 potentially highly exposed

Multiple specimens collected over time to characterize time changes of an exposure

Cross sectional sample of population

Broad profile of measurements investigating a health effect of unknown cause (e.g., cancer cluster)
Identifying ‘unusually high’ exposures

- Best if have health threshold level (e.g., lead $\geq 10 \, \mu g/dL$)

- In absence of health threshold level, 95th percentile can be used to define ‘unusually high’ exposures

(see data from Second National Report on Human Exposure to Environmental Chemicals, 2003 at www.cdc.gov/exposurereport)
CDC’s Second National Report on Human Exposure to Environmental Chemicals
Priority population groups for biomonitoring exposure assessment

- U.S. population and major U.S. demographic subgroups (today’s presentation)
- Special population groups with known or suspected elevated exposures
- Special populations with disease known or suspected to result from chemical exposures
Report Data

- 116 chemicals
- Selected participants in NHANES 1999-2000
- Blood and urine levels of chemicals and metabolites
- Sample size: 2000-2500 (more for cotinine, lead, cadmium)
Chemicals in the Second Report

- Lead, mercury, cadmium, uranium, thallium, other heavy metals
- Cotinine (tobacco smoke exposure)
- Dioxins, furans, and coplanar PCBs
- Non-coplanar polychlorinated biphenyls (PCBs)
- Polyaromatic hydrocarbons (PAHs)
Chemicals in the Second Report (cont’d)

• Organochlorine pesticides
• Organophosphate and carbamate insecticides
• Herbicides
• Phytoestrogens
• Phthalates
• Pest repellants and disinfectants
Public Health Uses of the *Report*

- what chemicals get into Americans
- how many people have elevated levels
- effectiveness of exposure reduction efforts
Public Health Uses (continued)

- **reference ranges** – identifying unusual exposure
- **levels in susceptible groups**, like women of childbearing age or children
- **priorities** for health research
For chemicals with limited health risk information:

Just because we can measure it, does not mean it is harmful
<table>
<thead>
<tr>
<th></th>
<th>Geometric mean (95% conf. interval)</th>
<th>Selected percentiles (95% confidence interval)</th>
<th>Sample size</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>10th</td>
<td>25th</td>
<td>50th</td>
</tr>
<tr>
<td><strong>Total, age 6 and older</strong></td>
<td>79.8 (69.0-92.2)</td>
<td>14.9 (11.8-18.4)</td>
<td>34.8 (28.3-41.7)</td>
</tr>
<tr>
<td><strong>Age group</strong></td>
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<tr>
<td>6-11 years</td>
<td>90.8 (72.2-114)</td>
<td>18.6 (14.8-36.3)</td>
<td>55.7 (39.8-69.9)</td>
</tr>
<tr>
<td>12-19 years</td>
<td>105 (85.0-129)</td>
<td>24.1 (19.2-33.5)</td>
<td>48.0 (39.5-61.4)</td>
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<tr>
<td>20+ years</td>
<td>74.8 (64.0-87.4)</td>
<td>13.6 (10.0-16.3)</td>
<td>30.7 (24.7-36.7)</td>
</tr>
</tbody>
</table>
| **Gender**               |                                    |                                |                     |                 |                 |                 |                     | \   
| Males                    | 90.1 (76.0-107) | 18.0 (14.1-23.5) | 37.1 (30.0-48.6) | 86.1 (73.2-99.8) | 227 (178-282) | 496 (401-577) | 751 (577-1020) | 1106 |  
| Females                  | 71.2 (61.6-82.3) | 13.7 (9.90-15.8) | 32.1 (26.6-36.9) | 70.9 (63.7-86.1) | 163 (149-197) | 361 (284-451) | 669 (387-940) | 1206 |  
| **Race/ethnicity**       |                                    |                                |                     |                 |                 |                 |                     | \   
| Mexican-Americans        | 74.2 (64.5-85.4) | 16.1 (14.3-19.6) | 34.0 (29.9-39.6) | 68.3 (59.5-82.8) | 161 (119-213) | 344 (268-463) | 545 (405-638) | 766 |  
| Non-Hispanic blacks      | 108 (87.0-135)  | 20.8 (17.9-24.0) | 46.6 (34.8-58.0) | 100 (76.2-148) | 245 (199-350) | 586 (420-778) | 812 (541-1360) | 528 |  
| Non-Hispanic whites      | 73.7 (61.1-88.9) | 13.8 (9.40-17.7) | 32.3 (24.3-39.7) | 72.9 (63.3-86.3) | 178 (153-222) | 399 (324-506) | 748 (451-977) | 831 |  

Table 58. 1-hydroxy pyrene
Geometric mean and selected percentiles of urine concentrations (in µg/L) for the U.S. population aged 6 years and older, National Health and Nutrition Examination Survey, 1999-2000.
Percent of children 1-5 years of age in the United States with blood lead levels $\geq 10 \ \mu g/dL$
Exposure of the U.S. population to tobacco smoke:
serum cotinine levels, 1988-1991

Serum cotinine (ng/mL)

Percent of the population

Non-smokers
(ETS exposure)

Smokers
Serum cotinine levels for non-tobacco users in the U.S. population, ages 17 and older, NHANES III, 1988-1991

Number of hours exposed at work

Geometric mean serum cotinine (ng/mL)
Decline in exposure of U.S. population to environmental tobacco smoke

Serum cotinine (50th percentile in ng/mL)

1988 - 1991: 0.20
1999-2000: 0.05
Decline in cotinine levels by age group

- Children: ↓ 58%
- Adolescents: ↓ 55%
- Adults: ↓ 75%
Cotinine levels, 1999-2000

Children – levels more than 2X adults

Non-Hispanic blacks - levels more than 2X whites or Mexican-Americans
Exposure to environmental tobacco smoke among casino workers
Exposure of casino workers to environmental tobacco smoke

Serum cotinine (geom. mean in ng/mL)

- No home or work exposure
- Work exposure only
- Home exposure only
- Home and work exposure
- Casino workers

NHANES NIOSH study
World Trade Center – detecting unusual levels of exposure

- 370 firefighters studied
- Blood and urine samples collected while fires still burning
- 110 fire related chemicals tested
  - PAHs
  - Metals
  - Cyanide
  - Dioxins/furans/PCBs
  - Volatile organic compounds
1-hydroxy pyrene levels in WTC firefighters

(geometric means in ng/L)

7.0% of exposed firefighters above 95th percentile of 2nd Report

1-hydroxy pyrene

Special Operations Firefighters
Other Firefighters
Control Firefighters
Adults – 2nd Exposure Report
Antimony levels in WTC firefighters

(geometric means in μg/L)

16.5% of exposed firefighters above 95th percentile of 2nd Report

Special Operations Firefighters
Other Firefighters
Control Firefighters
Adults – 2nd Exposure Report
U.S. troop exposure to depleted uranium in Iraq

- exposure from shrapnel
- exposure from battle explosions
- 0.045 µg/L is adult 95th percentile for urine uranium from 2nd Report
- to date, all soldier levels we have measured have been below this 95th percentile
Blood mercury levels in women of childbearing age (16-49 years), 1999-2000

- EPA reference dose for blood mercury is 5.8 µg/L
- In 2nd Report, the 95th percentile for women 16-49 years is 7.1 µg/L
- 7.8% of women of childbearing age exceed the EPA RfD
Future Directions for the *Report*

- **More chemicals**
  - VOCs (benzene, MTBE, toluene, styrene, others)
  - perfluorinated compounds
  - polybrominated diphenyl ethers (PBDEs)
  - speciated arsenic
  - separate measurements for methyl mercury and ethyl mercury
  - perchlorate
  - acrylamide
  - PAHs with 5 and 6 rings, the more carcinogenic PAHs
  - more …. 

- **New *Report* every two years**
www.cdc.gov/exposurereport