How Green Chemistry Could Help Reduce the Rates of Learning and Developmental Disabilities and Delays

Great Lakes Green Chemistry Network
Webinar
January 30, 2013

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The Changing Environment and Impacts on Health

- During the past century, human activity has altered virtually all aspects of the world’s ecosystems:
  - Pervasive spread of synthetic chemicals; air and water pollution.
  - Industrialized food supply.
  - Destruction of critical natural habitats, stressing ecosystems.

- How we live, eat, work, play and socialize have substantially changed:
  - Built environments have increased social isolation for many people; reduced physical activity.
  - Growing income gap increases risk of disease and disability and can exacerbate existing disabilities.
Interacting factors that influence health and development

- Heredity
- Gene-environment interactions
- Exposures to toxic chemicals
- Nutrition/food
- Infectious disease
- Socioeconomic status
- Psychosocial environment
- Access to nature
Early life experiences and exposures can influence later-life health

Toxic exposures, oxidative stress, Low birth weight

obesity, hypertension, cardiovascular disease, diabetes, intellectual and developmental disabilities and delays

Alzheimer’s, dementia, Parkinson’s

Aging begins at conception

Collaborative on Health and the Environment
Children’s Health Harms on the Rise, 1975 - 2011
Statistics on Specific Learning and Developmental Disorders

- **Learning and developmental disabilities (overall):** approximately 1 in 6 children under the age of 18 in the U.S. (CDC, “Trends in Prevalence” 1997-2008)
- **ADHD:** increased 6.3 – 9.5% in the period 1997-2010 for children ages 5-17 (EPA, America’s Children and the Environment, 2013)
- **Autism:** 1 in 88 children—a 10-fold increase 40 years (CDC, 2012)
- **Intellectual disabilities:** 2% or approximately 1.4 million children ages 5-17 – little change between 1997-2010 (EPA, America’s Children and the Environment, 2013)
- **Mental health concerns**—approximately 1 in 5 children under the age of 18 currently have or have had a serious debilitating mental illness (National Institute of Mental Health, NIH, 2010)
Early Exposures

- **Prenatal**
  - transplacental
  - developmental windows

- **Postnatal**
  - pound per pound children eat, drink and breath far more than adults
  - increased metabolic rate
  - increased time indoors & on floors
  - breast milk (*still best to breastfeed, but breast milk now contains many contaminants*)
Endocrine disrupting chemicals

Dose does NOT make the poison –

Laboratory experiments show that exposure to EDCs can have impacts at levels far lower than had been considered possible in traditional toxicology – and have different kinds of effects that may even be more serious depending on timing of exposure.
Epigenetics

- Possible epigenetic mechanism discovered
  (Hackett, et.al., 2013)
- Environmental factors that can alter how genes are expressed: potential impact on neurodevelopment
  (Zahir, et.al., 2011)
- Transgenerational epigenetics
  (Skinner, et.al., 2010)
Contemporary Prenatal Exposure to Endocrine Disrupting Chemicals

Percentage of U.S. Pregnant Women with Detectable Level of Analyte

Based on analysis of representative sample of U.S. population by NHANES 2003-2004. Note, not all women were tested for all chemicals


Slide credit: Patrice Sutton, MPH
Environmental agents that are known to interfere with healthy neurodevelopment:

- Lead
- Arsenic
- Mercury
- Solvents
- PCBs
- PAHs
- PBDEs
- Pesticides
- BPA
- Manganese
- Phthalates
- Dioxins *

*See “The Scientific Consensus Statement on Environmental Agents Affiliated with Neurodevelopmental Disorders” (2008)
Lead

- What was considered a “safe” threshold for exposure to lead continues to drop
- There is no safe level of lead exposure for children
- Global markets
- Environmental justice
- Similar for methyl-mercury exposure

**Acceptable Childhood Blood Lead Levels**

<table>
<thead>
<tr>
<th>Agency and Year</th>
<th>Blood Lead (ug/dl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CDC 1960</td>
<td>60</td>
</tr>
<tr>
<td>CDC 1973</td>
<td>40</td>
</tr>
<tr>
<td>CDC 1975</td>
<td>30</td>
</tr>
<tr>
<td>CDC 1985</td>
<td>25</td>
</tr>
<tr>
<td>WHO 1986</td>
<td>15</td>
</tr>
<tr>
<td>EPA 1986</td>
<td>15</td>
</tr>
<tr>
<td>CDC 1990</td>
<td>10</td>
</tr>
<tr>
<td>When?</td>
<td>2</td>
</tr>
</tbody>
</table>
Air pollutants - prenatal exposure to the common air pollutants – polycyclic aromatic hydrocarbons (PAHs) – can lower children’s IQ at kindergarten age.

(Perera, et. al., 2009)
PCB Effects on Thyroid Hormone

- **Altered thyroid hormone**
  - Mothers: Thyroid Hormone ↓ Thyroid Stimulating Hormone (TSH) ↑
  - Infants: Thyroid Hormone ↓ TSH ↑

- **Developmental Implications**
  Elevated maternal TSH during pregnancy, with or without reductions of thyroid hormone, associated with reduced IQ at age 7-9 yrs.
Bisphenol A

- Found in polycarbonate plastic, resins, dental sealants
- Exposures are nearly ubiquitous
- Endocrine disruptor
- Causes fat accumulation & insulin resistance at low levels (animals)
- 3-fold ↑ Cardiovascular disease (Lang, 2008)
- 2-fold ↑ Insulin Resistance (Lang, 2008)
- Neurotoxic – impacts cerebellar neurons during development (Le, 2009)
Cumulative stressors

*Human health*: multiple factors in disease and disability

- Chemical mixtures –
  study on PCBs + organochlorine pesticides exposure (Bowers, et. al., 2003)

- Chemical + stress –
  study on Pb + stress (Cory-Slechta, et. al., 2010)
## Economic Costs of Pediatric Environmental Diseases

### Estimated Costs of Pediatric Disease of Environmental Origin, United States, 1997 (billions)

<table>
<thead>
<tr>
<th>Disease</th>
<th>Best Estimate</th>
<th>Low Estimate</th>
<th>High Estimate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lead Poisoning</td>
<td>$43.4</td>
<td>$43.4</td>
<td>$43.4</td>
</tr>
<tr>
<td>Asthma</td>
<td>$2.0</td>
<td>$0.7</td>
<td>$2.3</td>
</tr>
<tr>
<td>Cancer</td>
<td>$0.3</td>
<td>$0.2</td>
<td>$0.7</td>
</tr>
<tr>
<td>Neurobehavioral Disorders</td>
<td>$9.2</td>
<td>$4.6</td>
<td>$18.4</td>
</tr>
<tr>
<td><strong>TOTAL</strong></td>
<td><strong>$54.9</strong></td>
<td><strong>$48.8</strong></td>
<td><strong>$64.8</strong></td>
</tr>
</tbody>
</table>

(From “Environmental Pollutants and Disease in American Children,” Landrigan, Schechter, et.al., 2002)
The Economics of IQ

➢ Economic value of one IQ point – $14,500 (median - year 2000 US$)

➢ Reducing blood lead levels by 10µg/dL raises IQ by 2.6 points = $37,700 in lifetime earnings per person – Landrigan, et. al., 2002

➢ Cohort of children with methymercury levels > 5µg/L = loss of economic productivity of $1.3 billion/year associated with emissions from American power plants - Transande, et. al., 2005

➢ Special education costs - $12,474 average per student in 1999-2000 (2.28 x cost of regular student) - US Dept of Education, 2004
“Mind, Disrupted” Biomonitoring Project

- First biomonitoring study on a health-affected group
- 12 participants
- Testing for 14 chemicals
- Media release
- Congressional briefing
- www.minddisrupted.org

Collaborative on Health and the Environment Learning and Developmental Disabilities Initiative
What can we do?
The Precautionary Principle

- 1998 Wingspread Statement
  - Exploring *alternatives* to possibly harmful actions, especially “clean” technologies that eliminate waste and toxic substances;
  - Placing the *burden of proof* on proponents of an activity rather than on victims or potential victims of the activity;
  - Setting and working toward *goals* that protect health and the environment; and
  - *Bringing democracy and transparency* to decisions affecting health and the environment.
Green chemistry is based on precaution

The Precautionary Principle put in action…

- **Theory**: Twelve principles
- **Toxicology**: understanding of the principles of toxicology, the molecular mechanisms of how chemicals affect human health and the environment, and the resources to identify and assess molecular hazards
- **Laboratory Skills**: the ability to recognize, assess and design greener alternative chemical products and processes

- Amy Cannon, Beyond Benign
Where to intervene in a system - the more effective, the more difficult

8. Material stocks and flows.
7. Regulating negative feedback loops.
6. Driving positive feedback loops.
5. Information flows.
4. The rules of the system (incentives, punishment, constraints).
3. The power of self-organization.
2. The goals of the system.
1. The mindset or paradigm out of which the goals, rules, feedback structure arise.

Donella Meadows; Places to Intervene in a System, 1997
Green chemistry - change the system, minimize neurotoxicity, improve society

Implementation of principles and practice of green chemistry – how could it impact the broader system?

Examples:

8. Material stocks and flows….
6. Driving positive feedback loops….
4. The rules of the system (incentives, punishment, constraints)….
2. Goals of the system
1. The mindset or paradigm out of which the goals, rules, feedback structure arise.

Designing chemicals to minimize neurotoxicity can improve the broader society in many ways….
Collaboration is key

- Join the Collaborative on Health and the Environment (CHE)
  www.healthandenvironment.org

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