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Fact sheets, journal publications, reports, and other resources for parents, community members, patients and healthcare professionals
Topics included: Air Quality, Pesticides, Natural Disasters, BPA, Mold, Lead, Mercury
Lead Poisoning and its Impact on School Readiness
How to Overcome the Toxic Effects

Jennifer A. Lowry, MD
Director, Division of Clinical Pharmacology, Toxicology and Therapeutic Innovations
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Children’s Mercy – Kansas City
This material was supported by the American Academy of Pediatrics (AAP) and funded (in part) by the cooperative agreement FAIN: 5 NU61TS000237-05 along with the American College of Medical Toxicology and funded (in part) by the cooperative agreement FAIN: 5U61TS000238-05 from the Agency for Toxic Substances and Disease Registry (ATSDR).

Acknowledgement: The U.S. Environmental Protection Agency (EPA) supports the PEHSU by providing partial funding to ATSDR under Inter-Agency Agreement number DW-75-95877701. Neither EPA nor ATSDR endorse the purchase of any commercial products or services mentioned in PEHSU publications.
At the end of the session, participants will be able to:

• identify multiple sources that may result in elevated lead levels in children

• describe the adverse health effects that can occur from lead exposure

• identify opportunities for children with lead exposures to optimize school readiness and ability to learn
How Do Children Get Lead Poisoned Today?

- Old paint
- Lead on the ground
  - From paint
  - From past use of leaded gasoline
  - Industrial sources – smelters
- Solder
Other Sources

As lead paint becomes less common, “Other” becomes proportionately more important.
Other Potential Sources Of Lead In The Environment

- Lead glazed pottery
- Jewelry and cosmetics
- Toys
- Lead water pipes
- Spices
- Firing ranges
- Casting ammunition, fishing weights or sinkers
- Renovating (e.g., ceramic tile, torching walls)
<table>
<thead>
<tr>
<th>Deficiency type</th>
<th>Problem observed</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Engineering control deficiencies</strong></td>
<td></td>
</tr>
<tr>
<td>Range ventilation system</td>
<td>Airflow at the firing line contained regions of backflow, causing lead to be carried back into the shooter’s breathing zone instead of downrange.</td>
</tr>
<tr>
<td></td>
<td>The range air supply diffusers produced turbulent jets of air, creating uneven air distribution at the firing line.</td>
</tr>
<tr>
<td></td>
<td>The downrange airflow was not evenly distributed and did not have the minimum recommended airflow of 30 ft/min (15 cm/sec).</td>
</tr>
<tr>
<td></td>
<td>The range filters did not have a minimum efficiency reporting value of 18 or 19, so contaminated air was released outside.</td>
</tr>
<tr>
<td></td>
<td>The range filters did not have side and face gaskets to prevent air from bypassing the filter; this allowed lead-contaminated air to be distributed to other areas served by the ventilation system.</td>
</tr>
<tr>
<td>Building ventilation system</td>
<td>Openings in the wall between the firing range and the rest of the building allowed lead to be circulated throughout the building.</td>
</tr>
<tr>
<td><strong>Housekeeping deficiencies</strong></td>
<td></td>
</tr>
<tr>
<td>Range housekeeping</td>
<td>Carpet and porous materials were present inside the shooting range.</td>
</tr>
<tr>
<td></td>
<td>Uniforms worn by employees who cleaned the range were reused, laundered infrequently, and stored in an open storage room.</td>
</tr>
<tr>
<td>Building housekeeping</td>
<td>Lead was detected on carpets, desks, tables, counters, eating surfaces, and ventilation supply and return air ducts outside the range. It was also detected inside the clean clothing bins and on towels that had been laundered by a commercial launderer.</td>
</tr>
<tr>
<td></td>
<td>Lead was detected on employees' shoes as they prepared to leave work.</td>
</tr>
<tr>
<td></td>
<td>No showering facilities were available for employees.</td>
</tr>
<tr>
<td></td>
<td>Employees' hands and street clothes were contaminated with lead.</td>
</tr>
<tr>
<td><strong>Medical surveillance deficiencies</strong></td>
<td>No employees had undergone the required medical surveillance.</td>
</tr>
<tr>
<td>Employees</td>
<td>The physician who evaluated employees to determine their fitness to wear a respirator did not complete the required forms properly.</td>
</tr>
</tbody>
</table>
Who is at greatest risk?

- Children < 3 years
- Immigrant, refugees and internationally adopted
- Children who live or attend daycare in a home built before 1960 (includes foster homes)
- Pregnant women

http://www.weekendcollective.com
Lead in U.S. children ages 1 to 5 years: Median concentrations in blood, by race/ethnicity and family income, 2009-2012

Data: Centers for Disease Control and Prevention, National Center for Health Statistics and National Center for Environmental Health, National Health and Nutrition Examination Survey

https://www.epa.gov/ace/biomonitoring-lead
<table>
<thead>
<tr>
<th>Blood Lead Level</th>
<th>Sufficient Evidence or Causal Determination of Children’s Health Effects</th>
</tr>
</thead>
</table>
| Below 5 µg/dL   | Nervous System Effects:  
|                 | - Cognitive function: Decreases in IQ, academic achievement, specific cognitive measures  
|                 | - Externalizing behaviors: Increased incidence of attention-related and problem behaviors |
| Below 10 µg/dL  | Effects listed above PLUS  
|                 | Nervous System Effects:  
|                 | - Auditory function: decreased hearing |
|                 | Reproductive and Developmental Effects:  
|                 | - Reduced postnatal growth  
|                 | - Delayed puberty for girls and boys |
| 10-40 µg/dL     | Effects listed above PLUS  
|                 | Nervous System Effects:  
|                 | - Nerve function: slower nerve conduction |
|                 | Blood Effects:  
|                 | - Decreased hemoglobin, anemia |
| 40-80 µg/dL     | Effects listed above PLUS  
|                 | Gastrointestinal Effects:  
|                 | - Abdominal pain, constipation, colic, anorexia and vomiting |
| Above 80 µg/dL  | Effects listed above PLUS  
|                 | Nervous System Effects:  
|                 | - Severe neural effects: convulsions, coma, loss of voluntary muscle control and death |
Neurodevelopment

The Impact of Elevated Blood Lead Levels
Prevention is Key

• Children cannot avoid negative impacts on neurodevelopment.
• Many children continue to be exposed through unsafe housing and under-identification of unsafe environments and children with past exposures.
<table>
<thead>
<tr>
<th>Blood Lead Levels</th>
<th>Educational Impact</th>
<th>Size of Study</th>
<th>Location of Study</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 3 µg/dL</td>
<td>Decreased end of grade test scores</td>
<td>More than 57,000 children</td>
<td>North Carolina (Miranda et al. 2009)¹</td>
</tr>
<tr>
<td>4 µg/dL at 3 years of age</td>
<td>Increased likelihood learning disabled classification in elementary school</td>
<td>More than 57,000 children</td>
<td>North Carolina (Miranda et al. 2009)¹</td>
</tr>
<tr>
<td></td>
<td>Poorer performance on tests</td>
<td>35,000 children</td>
<td>Connecticut (Miranda et al. 2011)</td>
</tr>
<tr>
<td>5 µg/dL</td>
<td>30% more likely to fail third grade reading and math tests</td>
<td>More than 48,000 children</td>
<td>Chicago (Evens et al. unpublished data)</td>
</tr>
<tr>
<td></td>
<td>More likely to be non-proficient in math, science, and reading</td>
<td>21,000 children</td>
<td>Detroit (Zhang et al. 2013)</td>
</tr>
<tr>
<td>5-9 µg/dL</td>
<td>Scored 4.5 points lower on reading readiness tests</td>
<td>3,406 children</td>
<td>Rhode Island (McLaine et al. 2013)</td>
</tr>
<tr>
<td>≥10 µg/dL</td>
<td>Scored 10.1 points lower on reading readiness tests</td>
<td>3,406 children</td>
<td>Rhode Island (McLaine et al. 2013)</td>
</tr>
<tr>
<td>10 and 19 µg/dL</td>
<td>Significantly lower academic performance test scores in 4th grade</td>
<td>More than 3,000 children</td>
<td>Milwaukee (Amato et al. 2012)</td>
</tr>
<tr>
<td>≥ 25 µg/dL</td>
<td>$0.5 million in excess annual special education and juvenile justice costs</td>
<td>279 children</td>
<td>Mahoning County, Ohio (Stefanak et al. 2005)</td>
</tr>
</tbody>
</table>
Epidemiologic studies suggest no discernible threshold for lead effects on IQ.

Deficits are measurable at least down to 5 mcg/dL.

Some evidence suggests impact may be greater at lower levels.
Mechanisms of Neurotoxicity

- Impact on brain sites/processes involved in impulse control (e.g., frontal and prefrontal lobes, dopaminergic systems).
- Cortical gray matter loss in prefrontal cortex with higher lead levels.
- Altered myelination and axonal integrity with early exposures.
- Pattern of “general dampening” of intellectual functioning that can be ascribed to several environmental causes.
Irreversible?

• Effects of early exposure to lead on IQ and other measures of cognitive attainment and behavior are not reversible through pharmacologic or nutritional interventions.

• Deficits related to early exposure are not reversible in the absence of educational interventions or other deficit related services.
Differs as a function of the child’s economic and social environment.

Some children may be at greater risk for poor academic performance compared to other children with similar blood lead levels.

Lead is “an equal opportunity neurotoxicant”
FIGURE 2
Proportion of children scoring above the fall PALS-K benchmark, by BLL.
School Readiness

• Association between moderate lead poisoning with elementary school end-of-grade exams.
  • 1133 families responded to survey
  • 43% had blood lead levels between 10 and 20 mcg/dL
  • Lead exposure was associated with significantly lower scores in all sections of end-of-grade exams
  • Children who were black, had a parent with less than a high school education, and were classified as having “less than excellent health” had significantly lower performance on all components

Magzamen et al. Annals of Epidemiology 2013
<table>
<thead>
<tr>
<th>Variable</th>
<th>Mathematics, OR (95% CI)</th>
<th>Science, OR (95% CI)</th>
<th>Reading, OR (95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Blood lead level, µg/dL (Ref = ≤ 1)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-5</td>
<td>1.42* (1.24, 1.63)</td>
<td>1.33* (1.10, 1.62)</td>
<td>1.45* (1.27, 1.67)</td>
</tr>
<tr>
<td>6-10</td>
<td>2.00* (1.74, 2.30)</td>
<td>2.22* (1.82, 2.72)</td>
<td>2.21* (1.92, 2.55)</td>
</tr>
<tr>
<td>&gt; 10</td>
<td>2.40* (2.07, 2.77)</td>
<td>2.26* (1.84, 2.78)</td>
<td>2.69* (2.31, 3.12)</td>
</tr>
<tr>
<td>Grade level (Ref = 5)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>0.36* (0.34, 0.38)</td>
<td>…</td>
<td>0.56* (0.53, 0.60)</td>
</tr>
<tr>
<td>8</td>
<td>1.62* (1.52, 1.74)</td>
<td>1.71* (1.59, 1.83)</td>
<td>0.99 (0.92, 1.06)</td>
</tr>
<tr>
<td>Gender: male (Ref = female)</td>
<td>1.11* (1.06, 1.17)</td>
<td>1.22* (1.14, 1.30)</td>
<td>1.38* (1.31, 1.46)</td>
</tr>
<tr>
<td>Race: Black (Ref = non-Black)</td>
<td>1.99 (0.98, 1.21)</td>
<td>1.11 (0.96, 1.28)</td>
<td>0.76* (0.68, 0.84)</td>
</tr>
<tr>
<td>Language: other (Ref = English)</td>
<td>1.16* (1.07, 1.26)</td>
<td>1.34* (1.22, 1.52)</td>
<td>1.29* (1.19, 1.40)</td>
</tr>
<tr>
<td>School lunch: free (Ref = paid)</td>
<td>1.56* (1.46, 1.66)</td>
<td>1.64* (1.51, 1.79)</td>
<td>1.45* (1.35, 1.54)</td>
</tr>
<tr>
<td>Maternal education: ≤ high school (Ref = &gt; high school)</td>
<td>1.25* (1.18, 1.33)</td>
<td>1.32* (1.20, 1.41)</td>
<td>1.37* (1.28, 1.45)</td>
</tr>
</tbody>
</table>

*Note. CI = confidence interval; OR = odds ratio. Science MEAP scores were restricted to grades 5 and 8. *P < .05.
Higher BLLs associated with greater magnitude and/or persistence among children from lower SEC.

Lower SEC associated with exposures to other neurotoxicants, poorer nutrition, inequities in medical coverage, increased stress, and fewer opportunities for stimulation.
Inter-Child Variability

- Magnitude of effects may vary depending on the characteristics of a particular child and his/her environment.
- Effects might be reduced by modifying critical aspects of the environment.
- Quality of early rearing environment may play role in magnitude and persistence of deficits.
Compelling evidence that children benefit from childrearing in an environment that has varied and age-appropriate educational opportunities and early intervention services.

“The course of development can be altered in the early childhood by effective interventions that change the balance between risk and protection, thereby shifting the odds in favor of more adaptive outcomes.”

Institute of Medicine (2000)
A nurturing, supportive home environment can positively influence developmental and behavioral outcomes.

No studies on impact of early childhood education interventions on neuro outcomes of lead, but...

Research demonstrates that children with developmental delays benefit from interventions at an early age.
Controversy over Lead-IQ link

The National Center for Environmental Health CDC

Educational Interventions for Children Affected by Lead

• Large number of confounders that must be considered when measuring an effect on children’s intelligence.

• Negative impact of lead on IQ persists in most recent studies following adjustment of confounders.

• Data is consistent that deficits are more prevalent in children in lower SES compared to higher SES and recovery is more likely to occur in those children above the median for social class, HOME score and maternal IQ (Dietrich 1991 and Bellinger 1991)

This paper was developed by an expert panel that included CDC and non-CDC authors.

April 2015

The information contained in this paper has been prepared and is presented for informational and educational purposes only. The information in this paper is not intended to be legal advice and should not be construed as legal advice or a legal determination about eligibility for any program or benefit.
Weiss B. 2000 EHP
Enrichment Environments

How can we help children with elevated lead levels?
<table>
<thead>
<tr>
<th>Condition</th>
<th>Behaviour</th>
<th>Neuroanatomy</th>
<th>Cellular/molecular</th>
<th>References</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brain injury or trauma</td>
<td>Improves memory and motor skills</td>
<td>Increases brain weight and dendritic branching</td>
<td>No data available</td>
<td>34,94–96,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>120,121</td>
</tr>
<tr>
<td>Stroke/ischaemia</td>
<td>Improves motor skills</td>
<td></td>
<td>Increases NGF A and glucocorticoid receptor mRNA levels; decreases BDNF mRNA levels</td>
<td>97,100,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>122,123</td>
</tr>
<tr>
<td>Epilepsy</td>
<td>Prevents seizures</td>
<td>Inhibits apoptosis</td>
<td>Enhances growth factor gene expression</td>
<td>72</td>
</tr>
<tr>
<td>Ageing</td>
<td>Improves memory</td>
<td>Increases neurogenesis; decreases gliogenesis and prevents decrease in synaptic density</td>
<td>Increases RNA content; increases NGF</td>
<td>14,36,69,</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>124–126</td>
</tr>
<tr>
<td>Stress</td>
<td>No effect</td>
<td></td>
<td></td>
<td>127</td>
</tr>
<tr>
<td>Huntington's disease mouse model</td>
<td>Enhances exploration and motor skills, and prevents seizures</td>
<td>Increases peristriatal cerebral volume</td>
<td>Delays disease onset</td>
<td>101</td>
</tr>
<tr>
<td>CA1 NMDAR1 knockout mice</td>
<td>Improves memory</td>
<td>Increases hippocampal synaptic and spine density</td>
<td>No data available</td>
<td>52</td>
</tr>
<tr>
<td>Prenatal alcohol</td>
<td>Improves memory</td>
<td></td>
<td>Improves cortical synaptic plasticity</td>
<td>35,128</td>
</tr>
<tr>
<td>Learning-impaired 129/SvJ mice</td>
<td>Improves memory</td>
<td>Enhances cell proliferation and neurogenesis</td>
<td>No data available</td>
<td></td>
</tr>
</tbody>
</table>

Enriched Environments

- Cognition and behavioral scores in 1st graders with history of lead exposure.
- Maternal support for a child’s school work and extracurricular activities has a greater influence on improved neurocognitive and behavioral outcomes than their own level of education.
- More research is needed on what enrichment interventions should look like.

Moodie et al. Neurotoxicology 2013
Head Start

- Focuses on children’s health, nutrition, mental health, and social service needs.
- Children must be low-income, recipients of public assistance, foster children, or homeless, or they must have a diagnosed disability.
- Children may begin the preschool experience at a disadvantage as compared with their counterparts in other early childhood education programs.
- Children experience significant gains in cognitive development.
Early Childhood Education: Effectiveness in Children with Disabilities

• Resulted in higher IQ scores, improved visual-spatial skills, and increased language development three to four years after the intervention as compared to children who received a parent training intervention alone.
• Increased ability to be in mainstream classrooms at kindergarten entry.
• Studies have shown gains are in similar areas that are affected by lead exposures.
How do we get children to the programs?
Federal Programs and Policies

• Individuals with Disabilities Education Act (IDEA) (20 U.S.C. § 1400 et seq.) Federal Special Education Law, including:
  • Child Find: Gateway to Services.
  • Part C: Early Intervention Services for Children Under Age 3.
  • Part B: Special Education for Children 3-21 Years Old, including Section 619 Preschool Programs and Coordinated Early Intervening Services.

• Rehabilitation Act of 1973, Section 504: Federal Civil Rights Protections

• Americans with Disabilities Act Amendments Act of 2008

• Medicaid: Early and Periodic Screening, Diagnosis and Treatment (EPSDT) Program

• Title V: Maternal and Child Health Block Grant
<table>
<thead>
<tr>
<th>Provision</th>
<th>Population</th>
<th>Services</th>
<th>Key Element</th>
<th>Activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDEA: Child Find</td>
<td>Children from birth–21 years of age, including those enrolled in all public and private schools.</td>
<td>Policies and procedures to identify, locate, and evaluate children suspected of having a disability.</td>
<td>Coordination with referral sources such as physicians and agencies.</td>
<td>Public awareness, referral, screening, eligibility determination, tracking, and interagency coordination.</td>
</tr>
<tr>
<td>IDEA: Part B</td>
<td>Children 3–21 years of age.</td>
<td>Provides for special education and related services.</td>
<td>Individualized education program (IEP) specifying services and supports the child will receive.</td>
<td>Education in the least restrictive environment appropriate. Early intervening services provide additional support to struggling students in general classroom.</td>
</tr>
<tr>
<td>IDEA: Part B, Section 619</td>
<td>Children 3–5 years of age (Section 619 preschool program).</td>
<td>Provides grants for preschool services.</td>
<td>Children with disabilities receiving services in inclusive settings.</td>
<td>Transition activities between IDEA Part C and Part B.</td>
</tr>
</tbody>
</table>

CDC. 2015. Educational Interventions for Children Affected by Lead
<table>
<thead>
<tr>
<th>IDEA: Part C</th>
<th>Children birth through third birthday. State option—extended Part C service from third birthday through kindergarten.</th>
<th>Provides early intervention services for infants and toddlers with developmental delays or diagnosed conditions with high probabilities of resulting in developmental delays.</th>
<th>Uses an individualized family service plan (IFSP) specifying services for a child and his/her family.</th>
<th>Provides services and education to children in their natural environment.</th>
</tr>
</thead>
<tbody>
<tr>
<td>IDEA: Part B, CEIS</td>
<td>Students from kindergarten through grade 12 (with a focus on kindergarten through grade 3).</td>
<td>Provides scientifically based academic and behavioral interventions.</td>
<td>Professional development for teachers and other school staff in scientifically based academic and behavioral interventions, including literacy instruction and, where appropriate, instruction on the use of adaptive and instructional software. Providing educational and behavioral evaluations, services, and supports, including scientifically based literacy instruction.</td>
<td></td>
</tr>
</tbody>
</table>
Child Find

• Ensures that no children with disabilities are denied a free appropriate public education because they have not been located.

• Ensure cooperation between educational agencies and others such as health, mental health, and developmental disabilities agencies; social services; corrections departments; private schools; and private agencies.

• Enables the states and local education agencies to appropriate funds, plan and deliver programs, and be held accountable to all children with disabilities.
Part C: zero to 3 years

- Provides funding for services to infants and toddlers with disabilities.
- Children must meet state’s eligibility definition of developmental delay OR have diagnosed physical or mental condition that carries the high probability of causing developmental delays.
- Established conditions include disorders secondary to exposure to toxic substances (e.g., fetal alcohol syndrome).
## Eligibility for Part C

<table>
<thead>
<tr>
<th>General Mention of Lead</th>
<th>Mention of Specific Elevated Blood Lead Level</th>
<th>General Mention of Exposure to Toxic Substances</th>
<th>No Reference to Lead Exposure</th>
</tr>
</thead>
</table>
Linking Education Community to Lead-Exposed Children EARLY

- Children who have been exposed to lead may not be identified in school records or appropriately tracked.
- Educators need information from lead poisoning prevention programs and providers to ensure that they understand and fulfill their unique roles.
Education for At-Risk Children

- Children with lead exposures at risk for academic failure but with different levels of delay.
- Connecting children to early education is key to reducing long-term effects.
- Early identification of children who can be helped at key transitions (1st, 4th, and 6th grades).
- Early behavioral interventions as children develop self-regulation and interpersonal skills.
Who must be at the table when a child is found to have an EBL?

- Health Department
- Department of Education/School District
- Health care provider
- Child care provider
- Parent
Summary

• Lead is known to cause adverse health effects in children at levels as low as 5 mcg/dL.
• Neurodevelopmental delays can occur but may not be seen until later in childhood.
• Enriched environments and early education have been shown to improve outcomes in children with developmental disabilities.
• Multidisciplinary approach at time of diagnosis may be key in improving outcomes for children.
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www.pehsu.net/nationalclassroom.html