Environmental Exposures and Reduced Cognitive Function in Children

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Figure 1.
Cumulative Frequency Distribution of Verbal IQ Scores in Subjects with Low or High Levels of Lead (n=158)

Figure 3.

Teachers' Ratings and Dentin Lead Levels (n=2146)

<table>
<thead>
<tr>
<th>CLASS</th>
<th>DENTIN LEAD (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>&lt; 5.1</td>
</tr>
<tr>
<td>2</td>
<td>5.1 - 8.1</td>
</tr>
<tr>
<td>3</td>
<td>8.2 - 11.8</td>
</tr>
<tr>
<td>4</td>
<td>11.9 - 17.1</td>
</tr>
<tr>
<td>5</td>
<td>17.2 - 27.0</td>
</tr>
<tr>
<td>6</td>
<td>&gt; 27.0</td>
</tr>
</tbody>
</table>

Figure 4.
Childhood Lead Exposure and Failure to Complete High School

Dentin Lead Quartiles (ppm) and Plumbism

<table>
<thead>
<tr>
<th>Quartile</th>
<th>Percent Failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 5.94</td>
<td>2/27</td>
</tr>
<tr>
<td>5.95-8.2</td>
<td>0/27</td>
</tr>
<tr>
<td>8.3-22.22</td>
<td>5/31</td>
</tr>
<tr>
<td>≥ 22.23</td>
<td>7/29</td>
</tr>
</tbody>
</table>

X = 28.6 (7-52)

Seven children still in school are not included.


Figure 5.
Childhood Lead Exposure and Reading Disability* in Young Adulthood

Dentin Lead Quartiles (ppm) and Plumbism

<table>
<thead>
<tr>
<th>Quartile</th>
<th>Percent Reading Disabled</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤ 5.94</td>
<td>4/30</td>
</tr>
<tr>
<td>5.95-8.2</td>
<td>4/31</td>
</tr>
<tr>
<td>8.3-22.22</td>
<td>6/30</td>
</tr>
<tr>
<td>≥ 22.23</td>
<td>12/31</td>
</tr>
</tbody>
</table>

X = 28.6 (7-52)

*Reading disability defined as 2 or more grades below expected.

FIGURE 1—Prevalence of Child Behavior Checklist subscale T-scores in clinical range (98th percentile), 2- to 3-year-old boys and girls (n = 118).

Sciarillo et al., Am J Public Health 82: 1356-1360, 1992
• There may be no lower threshold for some of the adverse effects of Pb in children.

• The harm that lead causes to children increases as their blood Pb levels increase.

• Blood Pb levels as low as 1µg/dL are associated with harmful effects on children’s learning and behavior.

• Very high blood lead levels cause devastating health consequences including seizures, come and death.
Figure 1. Restricted cubic splines and log-linear model for concurrent blood lead concentration. The dotted lines are the 95% CIs for the restricted cubic splines.

Figure 2. Linear models for each cohort study in the pooled analysis, adjusted for maternal IQ, HOME score, maternal education, and birth weight. The figure represents the 5th to 95th percentile of the concurrent blood lead level at the time of IQ testing.

Figure 3. Log-linear model (95% CIs shaded) for concurrent blood lead concentration, adjusted for HOME score, maternal education, maternal IQ, and birth weight. The mean IQ (95% CI) for the intervals <5 µg/dL, 5–10 µg/dL, 10–15 µg/dL, 15–20 µg/dL, and >20 µg/dL are shown.

Figure 4. Log-linear model for concurrent blood lead concentration along with linear models for concurrent blood lead levels among children with peak blood lead levels above and below 10 µg/dL.

Lanphear BP et al. (2005) EHP 113: 894-899.
### Effects of Lead on Cognitive and Behavioral Traits

<table>
<thead>
<tr>
<th>ADHD</th>
<th>LD</th>
<th>OTHER</th>
</tr>
</thead>
<tbody>
<tr>
<td>↑ hyperactivity</td>
<td>↓ reading, math</td>
<td>↓ fine motor</td>
</tr>
<tr>
<td>↑ impulsivity</td>
<td>↓ spelling</td>
<td>↓ visual motor</td>
</tr>
<tr>
<td>↑ distractibility</td>
<td>↓ pattern recognition</td>
<td>↑ aggressive</td>
</tr>
<tr>
<td>↑ dif. w. instructs</td>
<td>↓ word recognition</td>
<td>↑ antisocial</td>
</tr>
<tr>
<td>↑ conduct problems</td>
<td></td>
<td>↑ off-task</td>
</tr>
<tr>
<td>↓ executive function</td>
<td></td>
<td></td>
</tr>
<tr>
<td>↓ attention/vigilance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>↓ social skills</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 1. AOR for ADHD among U.S. children, NHANES 1999–2002, by blood lead concentration (µg/dL). The model was adjusted for child’s age, sex, race/ethnicity, preschool attendance, serum ferritin, prenatal ETS exposure, smoker in the household, and insurance status.

$p$-value for trend = 0.012.
Fig. 6. The 1979–1990 relation between IQ and white male incarceration risk (data derived from [51]). Data from the 1979 to 1990 National Longitudinal Survey of Youth (NLSY), a representative sample of American youths born in the late 1950s to mid-1960s, showed that less than 1% of white males with IQ over 110 reported being incarcerated before 1980, vs. 7% of those with IQ below 90. White males with IQ below 75 had an especially high prevalence of having one or more of their 1979–1990 annual NLSY interviews actually conducted in a correctional facility, suggesting a much higher risk of more serious (violent) offending among those in the lowest 5% of IQ.
Figure 1. Log-linear regression line for reading scores by serum cotinine levels. Dashed lines indicate 95% confidence interval.

Figure 2. Log-linear model for cotinine (solid line) versus linear models for cotinine among children with cotinine above and below 1 ng/mL (dashed lines; ~80th percentile).

Figure 2. AOR for ADHD among U.S. children by prenatal ETS exposure and sex. The risk for ADHD among ETS-exposed children was greater in females; females who were prenatally exposed to tobacco were at 4.6-fold higher risk for ADHD compared with unexposed females (OR = 4.6; 95% CI, 1.7–12.4), whereas exposed males were at 2-fold higher risk for ADHD compared with unexposed males (OR = 2.1; 95% CI, 0.9–4.7) \( (p = 0.141 \text{ for sex by prenatal ETS exposure interaction}) \). Model adjusted for race/ethnicity, sex, age, blood lead level, ferritin level, presence of a smoker in the home, preschool attendance, and insurance status.
DRAWINGS OF 4-YEAR OLD YAQUI CHILDREN WHO LIVE IN THE FOOTHILLS AS COMPARED TO THE VALLEY WHERE THEY ARE EXPOSED TO PESTICIDES IN SONORA, MEXICO. FROM GUILLETTE ET AL., 1998.
Polychlorinated Biphenyl

PCBs: A mixture of 209 congeners used in hydraulic fluids and transformers. Carcinogen, immune suppression, endocrine disruptor, neurotoxicity.
CHARACTERISTICS OF PCBS

PCBs are heavy oils that are relatively non-flammable and are good insulators.

They are very stable both in the environment and in the human body (half-life about 10 years).

PCBs bioaccumulate in the food chain and concentrate in fat. Animal products are the major source of exposure.

Lower chlorinated PCBs are both more water soluble and more volatile.

The polar regions of the earth are highly contaminated via atmospheric transport.
Neurotoxic Effects of Developmental PCB Exposure

- Decreased IQ
- Impulsivity
- Attention problems
- Poor school performance/language processing
- Deficient social behavior
- Blurring of gender-specific behavior
Chen et al., 1992
LAKE MICHIGAN STUDY SHOWS INTELLECTUAL IMPAIRMENT

Ø Assessment at age 11 (212):
167 fish eaters and 45 non-fish eaters.

Ø Results:
- Poorer short-term memory.
- Most highly exposed children had a 6.2 point in IQ.
- They were also 1 year behind in reading.
- Fish eaters children were all at the lower end of the normal range of intelligence.

Total Cognitive Score on K-ABC at 42 Months — Dutch Study

![Graph showing cognitive scores and PCB concentrations in maternal plasma (ug/l).]

- Cognitive Scale:
  - < 1.5
  - 1.5 - 1.99
  - 2.0 - 2.49
  - 2.5 - 2.99
  - >= 3.0

- PCB in Maternal Plasma (ug/l):
  - < 1.5
  - 1.5 - 1.99
  - 2.0 - 2.49
  - 2.5 - 2.99
  - >= 3.0
PCB-EXPOSED DUTCH CHILDREN SHOWED:

• Deficits in verbal comprehension on standard language development scale in relation to prenatal exposure.

• Slower reaction time with more false positives in a vigilance task.

• More aggression.

• Impaired immune system.

• Impaired thyroid function.
Dutch Studies of Behavioral Effects of Dioxins and PCBs

Children exposed prenatally showed decreased high-level play, while at the same time they were hyperactive and showed signs of being withdrawn or depressed. Prenatal PCB exposure was associated with more feminized play behavior in the boys, but more masculinized play behavior in the girls. Prenatal dioxin exposure was associated with more feminized behavior in both boys and girls.
Oswego Newborn & Infant Development Project

Ø Behavioral effects of neonates whose mothers consumed Lake Ontario fish.
Ø High fish eaters (>40 lb.), Low fish eaters (<40 lb.)
Controls had never eaten L.O. fish (self-report)
Ø Cord blood/ breast milk were taken for PCB analysis
Ø Infants in the high exposure group showed:
  - Abnormal reflexes
  - Less mature autonomic responses
  - Less developed attention to visual & auditory stimuli
  - Delayed habituation

Fagan Test of Infant Intelligence
12 Months — Oswego Study

Gaze at Novel

<table>
<thead>
<tr>
<th>Total PCBs (ppb)</th>
<th>0 (ND)</th>
<th>&gt; 0</th>
<th>&gt; .02</th>
<th>&gt; .09</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>57</td>
<td>59</td>
<td>61</td>
<td>65</td>
</tr>
</tbody>
</table>

Diagram showing the gaze at novel for different levels of total PCBs.
WE GAVE ADOLESCENTS FOUR IQ TESTS

- We found that the higher the PCB level in the blood, the less well the adolescents did on each of these four tests.
CORRELATIONS BETWEEN PCBS AND COGNITIVE VARIABLES IN MOHAWK ADOLESCENTS.
(CONTROLLING FOR CONFOUNDING VARIABLES)
COEFFICIENTS WITH * ARE STATISTICALLY SIGNIFICANT (P<.05) ALL OTHERS LISTED ARE SIGNIFICANT AT (P<.1).

<table>
<thead>
<tr>
<th>PCB Grouping Variables</th>
<th>Cognitive Tests And Effects of PCBs</th>
</tr>
</thead>
<tbody>
<tr>
<td>50% Detect</td>
<td>Delayed Recall (-0.13)*</td>
</tr>
<tr>
<td></td>
<td>Long Term Retrieval (-0.19)*</td>
</tr>
<tr>
<td></td>
<td>Comprehension Know. (-0.14)*</td>
</tr>
<tr>
<td></td>
<td>Auditory Processing (-0.11)</td>
</tr>
<tr>
<td>75% Detect</td>
<td>Delayed Recall (-0.14)*</td>
</tr>
<tr>
<td></td>
<td>Long Term Retrieval (-0.18)*</td>
</tr>
<tr>
<td></td>
<td>Comprehension Know. (-0.13)*</td>
</tr>
<tr>
<td></td>
<td>Auditory Processing (-0.11)</td>
</tr>
<tr>
<td>Highly Chlorinated</td>
<td>Delayed Recall (-0.14)*</td>
</tr>
<tr>
<td></td>
<td>Long Term Retrieval (-0.19)*</td>
</tr>
<tr>
<td></td>
<td>Comprehension Know. (-0.13)*</td>
</tr>
<tr>
<td>Persistent PCBs</td>
<td>Delayed Recall (-0.15)*</td>
</tr>
<tr>
<td></td>
<td>Long Term Retrieval (-0.16)*</td>
</tr>
<tr>
<td></td>
<td>Comprehension Know. (-0.12)</td>
</tr>
<tr>
<td></td>
<td>Auditory Processing (-0.114*)</td>
</tr>
</tbody>
</table>
WHAT ABOUT ADULTS?

• We tested about 350 adults with memory and IQ tests.
• Individuals with higher blood PCB levels did not do as well on these tests as those people with lower levels.
Figure 8. Age Related Threshold Effect of PCBs on Grooved Pegboard Latent Variable
FIG. 2. The number of sessions required for control and PCB-treated monkeys to learn a spatial alternation task. Each symbol represents an individual monkey (from Rice and Hayward, 1997).
RESPONSE BURSTS

Mean Responses (IRT ≤ 1s)

GROUPS

MC  MFF  FC  FFF
Mercury Effects of Low Dose Prenatal Exposure

Figure shows prenatal mercury exposure levels of Faroese children with scores in the lowest quartile after adjustment for cofounders. For each of the five major cognitive functions, one neuropsychological test with a high psychometric validity was selected.

<table>
<thead>
<tr>
<th>Function</th>
<th>&lt; 15 µg/l</th>
<th>15-30 µg/l</th>
<th>30-50 µg/l</th>
<th>&gt; 50 µg/l</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOTOR</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ATTENTION</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VISUOSPATIAL</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LANGUAGE</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>MEMORY</td>
<td></td>
<td></td>
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</tbody>
</table>


Figure shows prenatal mercury exposure levels of Faroese children with scores in the lowest quartile after adjustment for cofounders.
Mercury Exposures

Current exposures

• >10% of women of reproductive age exceed Reference Dose (RfD)

• 50% of women who eat fish exceed RfD on any given day

• Higher risk: Subsistence fishers, immigrants, Native Americans
The Significance of Small Effects: EFFECTS OF A SMALL SHIFT IN IQ DISTRIBUTION IN A POPULATION OF 260 MILLION

5 Point Decrease in Mean IQ

I.Q. 70 130

mean 100

6.0 million "mentally retarded"
6.0 million "gifted"

mean 95

57% INCREASE IN "Mentally Retarded" Population

9.4 million "mentally retarded"
2.4 million "gifted"
GASEOUS RELEASES WITH NATURAL GAS

- Volatile organic compounds (VOCs): Many including methane, benzene, methylbenzenes, ethylbenzene, xylene, pentane, hexane, toluene, 1,3-butadiene and a variety of aliphatic hydrocarbons.
- Formaldehyde.
- Hydrogen sulfide.
- Radon.
- All of the above have adverse health effects on humans.
AIR POLLUTION CAUSES OTHER DISEASES AS WELL

- Both particulate and VOC air pollution cause increased risk of asthma, respiratory infections and chronic obstructive pulmonary disease.
- Immediate health effects include headaches, dizziness, eye, nose and throat irritation, visual disorders, memory problems, fatigue, nosebleeds
- Silica causes silicosis, a restrictive lung disorder.
- Some VOCs are endocrine disruptors.
- Others cause liver or kidney damage.
OTHER HUMAN HEALTH EFFECTS OF VOCs

• Occupational studies report three levels of severity of VOC exposure on the brain and behavior:
  • **Organic affective syndrome**: Depression, irritability
  • **Mild chronic toxic encephalopathy**: Fatigue, mood disturbances, memory and attention complaints.
  • **Severe chronic toxic encephalopathy**: Loss of intellectual abilities, impaired judgment and memory, personality changes
OZONE

- Studies have shown that ozone cause inflammation of the respiratory tract and increases risk of asthma attacks.
- Ozone combines with VOCs to form smog.
- Colorado, Wyoming, Texas and Utah have all recorded ozone levels that exceed federal limits.
  - Wyoming and Utah have ozone measurements higher than the worst days in Los Angeles.
  - May be difficult for some areas to meet the federal limits until new regulations go into effect limiting flaring and requiring “green completion” technology.
PARTICULATE MATTER

- Particulate matter (PM) comes from diesel exhaust from machinery and trucks, dust from gravel roads.
- Prenatal exposure to PM has been associated with low birth weight.
- Exposure during pregnancy and first year of life has been associated with increased risk of autism.
- Elevated PM increases risk of asthma and respiratory symptoms, such as coughing, difficulty breathing, and respiratory infections.
- People with underlying cardiovascular disease are at greater risk of death on days with elevated particulate air pollution.
Figure 1. Association of symptoms and distance from facilities, by age group

Symptoms experienced by respondents 16 years-old or younger

- % experiencing symptom
- Throat irritation
- Increased fatigue
- Sinus problems
- Nasal irritation
- Eye burning
- Shortness of breath
- Joint pain
- Severe headaches
- Feeling weak and tired
- Sleep disturbances
- Forgetfulness
- Lumbar pain
- Muscle aches or pains
- Difficulty breathing
- Frequent nausea
- Skin rashes
- Frequent nose bleeds

Legend:
- All distances from facilities
- Those living with a facility 1500 feet or closer
CONCLUSIONS

• Exposure to several environmental contaminants cause a similar profile of reduced cognitive function accompanied by adverse behavioral effects. These are precisely the characteristics of attention deficit hyperactivity disorder (ADHD). VOCs, such as those found near oil and gas sites, also alter nervous system function. While children are most vulnerable, adults also show the same effects.