INTRODUCTION

Attention concerning the hazards of lead in our everyday lives has recently focused nationally on toys and candies, and locally on the water fountains in our schools. Despite these worrisome “new” sources of lead exposure, the overall trend in Southern California over the last decade has been extremely positive. Screening for lead poisoning has become much more comprehensive and the average blood lead level in both adults and children has dropped significantly.

Lead poisoning is primarily a problem for children under the age of six, both because they tend to be more “auto-oral exploratory” (i.e., they put more things in their mouths) than older children and adults, and because children exhibit more pronounced health symptoms than do adults at the same blood lead level. In addition, lead poisoning is particularly troubling in young children because the neurobehavioral problems caused by low levels of lead exposure at this age can be permanent; they do not necessarily recede when the exposure to lead ends.

This article summarizes our understanding of the effects of lead exposure on children’s health, and explains why the focus of the pediatric and environmental health communities has shifted toward prevention of lead poisoning. We discuss the potential risks that some of the highly publicized “new” sources of lead exposure
pose to our children’s health, and the trends in lead poisoning rates in both the general population and in vulnerable populations in Southern California over the last decade.

**LEAD POISONING AND NEUROBEHAVIORAL PROBLEMS**

Lead has been recognized as a poison for thousands of years, but the profound impact that chronic exposure to even low levels of lead can have on developing children only became widely recognized in the United States in the 1970s. At that time, it was not uncommon for pediatricians to see lead poisoning cases in which the children had blood lead levels greater than or equal to 45 micrograms per deciliter (µg/dL), at which point children often exhibit both neurological problems and anemia. At higher blood lead levels (70-100 µg/dL), children can suffer from comas and seizures, or even die.

Today, childhood deaths from lead poisoning are extremely uncommon and most pediatric lead poisoning occurs in children with blood lead levels in the range of 10-20 µg/dL. Classic epidemiological studies by Herbert Needleman and coworkers in the 1970’s demonstrated that children with blood lead levels even in the moderate range are more likely to have lower IQ scores and shortened attention spans than children with “baseline” blood lead levels. Many of the laboratories in the country that perform blood lead tests use equipment that cannot reliably detect lead levels below 2-3 µg/dL. Hence, instead of saying that a child has a blood lead level of “0” if no lead is detected, most laboratories will report that the baseline level is less than or equal to 2-3 µg/dL.

One of the confusing aspects of lead poisoning is that the symptoms exhibited by different individuals at a particular blood lead level vary considerably. The biological basis for this variability is an active area of research. The hope is that if we can understand what factors contribute to an increased susceptibility to lead poisoning, we could predict which children are at greatest risk and work particularly hard to prevent exposure in those individuals. Because of this variability, the Centers for Disease Control (CDC) always refers to a child as having an “elevated” blood lead level – i.e., a level above which symptoms are frequently seen in children – as opposed to calling a child “lead poisoned”. The term “lead poisoned”, which is used more frequently in the general community, suggests the child is experiencing adverse symptoms as a result of exposure to lead.
Figure 1. The average blood lead levels (BLLs, shown in green) in the United States has dropped significantly since the mid 1970s, due to a ban on use of leaded paint in homes and phasing out of leaded gasoline. Over the same period, our understanding of the adverse effects of lead has improved and therefore the BLL that the CDC considers to be elevated (shown in red) has also dropped dramatically. Most experts consider no level of lead to be safe for children. The units used for BLLs are micrograms per deciliter (µg/dL).

The level the CDC defines as “elevated” has dropped significantly since the 1960’s, in response to clear evidence even very low levels of lead are harmful to children’s health (Figure 1). Currently, the CDC defines an “elevated” blood lead level as one that is greater than or equal to 10 µg/dL (Table 1). In 1976, the average child in the United States had a blood lead level of approximately 16 µg/dL, suggesting a person who grew up in the United States in the 1970’s (including the author) was exposed to lead levels currently considered to be unacceptable. Although many of us have gone on to conduct successful and rewarding lives despite this exposure, it is important to note the most pronounced impacts of this exposure are likely to have been felt by those individuals whose IQ or neurological development was already marginal. Whereas a drop in IQ of 5-10 points does not significantly alter the functioning of individuals at the top end of the IQ distribution, it can have a devastating effect on those individuals who are at the low end of the distribution.

Recent studies suggest these declines in cognitive outcomes often persist long after the source of exposure has been removed. Perhaps even more disturbing, treatment of children with chelation therapy who have blood lead levels between 25 and 44 µg/dL does not significantly improve their cognitive outcomes later in life compared to children who received no chelation therapy but simply had the source of exposure removed. In addition, studies suggest individuals who suffer from chronic lead poisoning during early childhood are more likely to behave violently and engage in criminal behavior later in life.
Epidemiological studies have consistently demonstrated that average IQ scores in children decrease with increasing blood lead level. One recent study showed that each increase in BLL of 10 µg/dL is associated with a decrease in IQ score of ~4.6 points. The average IQ score in the United States is 100. An IQ score of 70 is generally considered to be the benchmark for mental retardation, with the severity of retardation increasing as the IQ score decreases. (An IQ score of 50-70 corresponds to mild mental retardation; an IQ score of 35-50 corresponds to moderate mental retardation; an IQ score of 20-35 corresponds to severe mental retardation; and IQ score less than 20 corresponds to profound mental retardation.) Although a difference of 5-10 IQ points is not expected to have a pronounced effect on functioning for individuals at the high end of the IQ distribution, it can have a profound impact on those individuals at the low end of the IQ distribution. In addition, a shift in the average IQ score from 100 (red line) to 90 (green line) or even 95 (blue line) has a pronounced influence on the percent of the population that classifies as moderately retarded (brown shading). A corresponding decrease in the percent of the population that is gifted (IQ score of 125-134) or highly gifted (IQ score of 135-144) also occurs (purple shading).

A SHIFT TOWARD PRIMARY PREVENTION

An important take-home message from all of these studies of the effects of lead poisoning is that it is better to prevent lead poisoning from happening in the first place than to treat lead poisoning after it has occurred, an approach often referred to as "primary prevention of lead poisoning". Indeed, the last ten years have seen a growing emphasis in the pediatric and environmental public health communities on the following interventions aimed at decreasing the number of children who suffer from lead poisoning:

- Identification and reduction of primary sources of exposure;
- Universal screening of children who fall in one or more categories of “vulnerable populations”;
- Increasing awareness of lead poisoning and how it can be prevented, particularly in vulnerable populations;
- House visits by public health practitioners to families of individuals who test high, to educate parents and caregivers and to identify possible sources of exposure.
A wide range of studies have consistently demonstrated the primary source of lead poisoning in children in the United States is exposure to leaded paint. Lead paint was used extensively in the United States for the first part of the last century and was not banned for residential use until 1978. Unless the lead paint has been removed or mitigated by a contractor specifically licensed to deal with lead hazards, it is highly likely to persist in the home. Over 40% of homes built between 1940-1959 and over 65% of homes in the United States built prior to 1940 still contain hazards due to leaded paint. The lead from the paint gets incorporated into household dust and is both inhaled and ingested by small children, who are prone to putting play items in their mouths as they explore their surroundings. Simply painting over lead paint does not remove the hazard and in some cases can make it worse. Build up of layers of paint on doors and windows can increase the amount of friction when they are opened and closed and can result in a greater release of lead-contaminated dust. In addition, renovations in areas containing leaded paint can cause large amounts of lead to be released and can result in acute lead poisoning in the children who live in the home, especially if the renovations are not performed with appropriate precautions. Legislation focused on reducing this source of exposure has focused both on required notification about known lead hazards in residences and on ensuring that homes containing lead hazards are renovated using appropriate precautions. Before starting any renovations, parents of young children who live in a home built before 1978 should check for the presence of lead paint, either by using a home test kit or by hiring a licensed lead inspector.

Before starting any renovations, parents of young children who live in a home built before 1978 should check for the presence of lead paint, either by using a home test kit, which can be purchased for about $20 at most hardware stores, or by hiring a licensed lead inspector or risk assessor. If the home is found to contain lead, only a contractor licensed to perform lead removal should be hired and parents should consider moving children out of the home while the renovations are being performed and until a “safe” clearance of the lead is achieved. (A list of licensed lead inspectors, risk assessors, and contractors in the state of California can be found at: www.cdph.ca.gov/programs/CLPPB.)

The second most common source of lead exposure in the United States is lead-contaminated soil. Soil in most urban areas in the U.S. (including the greater Los Angeles area) tends to be highly contaminated by lead emitted by cars fueled by leaded gasoline. Although use of leaded gasoline was effectively eliminated in the United States in the 1980s due to widespread incorporation of catalytic converters in automobiles and trucks, the old lead emitted by motor vehicles and deposited in the soil decades ago still remains. In addition, houses painted with lead paint often...
have extremely high soil lead levels in the immediate proximity of the house. Lead in soil is not only a problem because small children often put their hands in their mouths when playing outside; soil is also easily tracked into homes by people and pets, where it too is incorporated into household dust.

Parents can reduce their children's exposure to lead from these sources by wet-mopping floors and removing dust with a wet cloth (instead of sweeping and dry-dusting); removing shoes prior to entering the house; not allowing children (and pets) to play in areas containing bare soil; and frequently washing their children's faces and hands. A good diet also goes a long way. Diets rich in nutrients, such as iron, calcium, and zinc, and low in fat have been shown to reduce the amount of lead that children (and adults) absorb into their bodies for a given exposure.

Screening children for lead poisoning is often referred to as "secondary prevention" of lead poisoning. Although it does not completely prevent a child from being lead poisoned, it allows children who are lead poisoned to be identified early so the exposure can be eliminated before it does more damage. The CDC and the American Academy of Pediatrics recommend all children who are Medicaid eligible be screened for blood level, ideally at one year of age and again at two years of age (or anytime before age 6 years if they were not tested at age 24 months). Children who are Medicaid-eligible are categorized as a "vulnerable population" because they are more likely to live in lead-contaminated housing and are much more likely to have an elevated blood lead level than the average non-eligible child living in the same state or region. Additionally, the state of California recommends that all children under the age of six who "live in, or spend a lot of time in, a place built before 1978 that has peeling or chipped paint or that has been recently remodeled" (or whose parents answer "I don’t know" when asked whether their child lives or spends a lot of time in such a place) be screened for lead poisoning. In addition, because the incidence of lead poisoning is often higher in other countries (particularly in the developing world), recent immigrants, refugees, or international adoptees should be screened upon their arrival in the United States.

In most cases, the recommended method for “managing” an elevated blood level (Table 1) is to educate the family about how to minimize the child’s exposure and to follow that child more closely to ensure the exposure is not continuing or becoming worse. Only blood lead levels greater than 20 µg/dL trigger an “environmental investigation” i.e., a public health or environmental health practitioner being sent to the child’s house to determine likely sources of exposure so that they can be eliminated. Chelation therapy is only recommended by the CDC in cases where a child exhibits a blood lead level greater than or equal to
45 µg/dL, primarily because the risks associated with chelation therapy (which can deplete the body of necessary nutrients such as calcium, iron, and zinc) are not insignificant and advantages to chelating (over just ceasing exposure) have only been seen in cases where the lead level is quite high. Administration of oral chelating agents without first decontaminating the bowel has resulted in highly undesirable increased lead uptake from the intestines in some cases. As a result, chelation therapy should only be performed under the supervision of a licensed physician.

**SYSTEMATIC LOWERING OF LEAD POISONING RATES**

As a result of the ban on the use of lead paint in homes, phase-out of leaded gasoline, and focus on reducing children’s exposure to lead, lead poisoning rates in the United States have dropped dramatically over the last thirty years (Figure 1). California has significantly increased the number of children who are screened for lead poisoning to ~600,000 children per year. Even though the number of children tested each year has increased by several orders of magnitude, the number of cases of elevated blood lead reported within the state has dropped markedly. In Los Angeles County (http://publichealth.lacounty.gov/lead/reports/leaddata_new.htm), only 416 children were reported with elevated lead levels in 2007, 65% of which had lead levels between 10 and 14 µg/dL and only 3% of which had blood lead levels greater than or equal to 45 µg/dL. This is a dramatic improvement over just ten years earlier, when many fewer children were tested but 1184 reports of children with elevated lead levels were made in Los Angeles County, 28% of which had lead levels between 10 and 14 µg/dL and 14% of which had blood lead levels greater than or equal to 45 µg/dL.

Many of these cases continue to be clustered in regions of the city which have high numbers of babies delivered on Medi-Cal (which is a good proxy for children aged 1-2 years who are on Medi-Cal) and which have high numbers of housing units built before 1950. As a result, the Los Angeles County Department of Public Health’s Lead Poisoning Prevention Branch has developed a prevention program that prioritizes educating parents of young children in these at risk populations about the risks of lead poisoning and the importance of reducing possible exposures and screening their young children (Figure 3). This strategy includes developing posters and fliers in Spanish highlighting potential sources of exposure that are more common in children of recent immigrants from Mexico and Latin America and working with community-based organizations in underserved communities to improve outreach and screening in those communities.
“NEW” (AND NOT SO NEW) SOURCES OF LEAD EXPOSURE

Several “new” sources of lead poisoning have made headlines over the last five years, including lead-contaminated candies (many imported from Mexico), lead-contaminated toys (mainly from China), and lead-contaminated drinking water in Los Angeles Unified School District (LAUSD) schools. These sources have emerged as priorities because exposure to other (historically more common) sources of lead, including lead-contaminated paint, household dust, and soil has declined. The “new” sources are worrisome both because they can lead to sporadic cases of fairly high blood lead levels (and in the case of lead contaminated toys have even resulted in some deaths nationwide) and because they are in products specifically targeted at children. In
response to disclosure from the local media in 2002-2004 that several types of imported candies contained lead, the California Assembly passed a bill (Assembly Bill No. 121) charging the Food and Drug Branch of the California Department of Public Health with preventing the sale of adulterated candy to infants, young children, and pregnant women. As a result of these efforts, systematic testing of candies for lead contamination has been conducted for a number of years. The actions the State has taken against manufacturers of contaminated candies has resulted in a significant decrease in the number of contaminated candies on the market (see www.leadinmexicancandy.com/safe_candy.html for a list of candies that have tested as “safe” from lead).

Over the last two years, the Consumer Product Safety Commission (CPSC) has recalled hundreds of thousands of toys and other consumer products found to be tainted with lead (see www.cdc.gov/nceh/lead/Recalls/default.htm). These products, many of which contain lead paint and were imported from China, have raised concerns about how to adequately monitor supply chains for products manufactured in developing countries, many of which have less strict environmental regulations than the United States. In response to these problems and the ensuing public outcry, the Congress passed the Consumer Product Safety Improvement Act of 2008 (Public Law 110-314) which prescribes a timeline for decreasing the amount of lead that is allowed in children’s products. Pursuant to this act, the CPSC issued a ruling that products manufactured after February 10, 2009 that are designed for, or intended primarily for, children under the age of 12 may not contain more than 600 parts per million (ppm) lead on any of their accessible parts.

Closer to home, the local media reported in 2008 that several drinking fountains in elementary schools in the LAUSD contained water with lead levels higher than the national standard for drinking water. In response, LAUSD launched a program to comprehensively test water in schools across the district, which revealed the problem is more widespread, and in some cases more severe, than originally reported. Nonetheless, the number of children affected and the magnitude of the exposures typically seen for these “new” sources are relatively small compared to the number of children and their exposures in the second half of the 20th century in the United States and compared to conditions that persist to this day in many third world countries.
CONCLUSION AND GRADE

Overall Grade: A-

Overall, the amount of lead children are exposed to in Southern California and the number of cases of childhood lead poisoning have dropped dramatically over the last couple of decades, due in large part to both environmental legislation and ongoing efforts from the public health community.

Grade for Persistent Impacts on Vulnerable Populations: B-

Nonetheless, it is clear some of the poorest and most vulnerable children within our community continue to be disproportionately effected by lead poisoning, even though lead poisoning is completely preventable.

RECOMMENDED READING / WHERE TO GET MORE INFORMATION


• California Department of Public Health – Childhood Lead Poisoning Prevention Branch (www.cdph.ca.gov/programs/CLPPB)

• Los Angeles County Department of Public Health – Childhood Lead Poisoning Prevention Branch (publichealth.lacounty.gov/lead)
**Table 1. Definitions and current recommended strategies for managing elevated blood lead levels.**

<table>
<thead>
<tr>
<th>Blood Lead Level</th>
<th>Recommended Management Strategy</th>
</tr>
</thead>
<tbody>
<tr>
<td>2-3 µg/dL</td>
<td>Detection Limit of Current Instrumentation</td>
</tr>
<tr>
<td>≥ 10 µg/dL</td>
<td>Elevated</td>
</tr>
</tbody>
</table>
| 10-14 µg/dL      | • Educate family and caregivers about proper diet and how to minimize environmental exposures  
|                  | • Follow-up blood lead monitoring |
| 15-19 µg/dL      | • Educate family and caregivers about proper diet and how to minimize environmental exposures  
|                  | • Follow-up blood lead monitoring  
|                  | • Proceed according to actions for 20-44 µg/dL if either:  
|                  | ◦ follow-up BLL is in this range at least 3 months after initial venous test, or  
|                  | ◦ BLLs increase |
| 20-44 µg/dL      | • Educate family and caregivers about proper diet and how to minimize environmental exposures  
|                  | • Follow-up blood lead monitoring  
|                  | • Complete history and physical exam  
|                  | • Lab work:  
|                  | ◦ Hemoglobin or hematocrit  
|                  | ◦ Iron status  
|                  | • Environmental investigation  
|                  | • Lead hazard reduction  
|                  | • Neurodevelopmental monitoring  
|                  | • Abdominal X-ray (if particulate lead ingestion is suspected) with bowel decontamination if indicated |
| 45-69 µg/dL      | • Educate family and caregivers about proper diet and how to minimize environmental exposures  
|                  | • Follow-up blood lead monitoring  
|                  | • Complete history and physical exam  
|                  | • Lab work:  
|                  | ◦ Hemoglobin or hematocrit  
|                  | ◦ Iron status  
|                  | ◦ FEP (free erythrocyte porphyrins) or ZPP (zinc protoporphyrin)  
|                  | • Environmental investigation  
|                  | • Lead hazard reduction  
|                  | • Neurodevelopmental monitoring  
|                  | • Abdominal X-ray (if particulate lead ingestion is suspected) with bowel decontamination if indicated  
|                  | • Chelation therapy |
| ≥ 69 µg/dL       | Acute  
|                  | • Hospitalize and commence chelation therapy  
|                  | • Proceed with actions recommended for 45-69 µg/dL |
AUTHOR BIO

Professor Hilary A. Godwin joined the UCLA faculty in 2006 and is currently a Professor in the Environmental Health Sciences Department and Associate Dean for Academic Programs in the School of Public Health. She is also a member of the Institute of the Environment and the California Nanosystems Institute. She received a B.S. in Chemistry from the University of Chicago and a Ph.D. in Physical Chemistry from Stanford University. Prior to joining the faculty at UCLA, Dr. Godwin was Chair of the Department of Chemistry at Northwestern University. Dr. Godwin has received several awards, including a Camille Dreyfus Teacher-Scholar Award, an Alfred P. Sloan Research Fellowship, a National Science Foundation CAREER Award, a Burroughs Wellcome Fund Toxicology New Investigator Award, and a Camille and Henry Dreyfus New Faculty Award. She is a Howard Hughes Medical Institute Professor. Dr. Godwin’s research focuses on elucidating the molecular toxicology of lead and also works actively with community groups to prepare for and diminish the impact of climate change on public health.

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