Issue 25

LEAD

KEY QUESTIONS

- How does exposure to lead affect human health?
- What are sources of lead exposure?
- What are the trends in lead emissions?
- Who is responsible for regulating lead as an environmental health hazard?

ENVIRONMENTAL HEALTH

People living in the developed West are becoming increasingly concerned about the safety of their food. In Europe, beef bans have been enacted due to fears of "Mad Cow" disease. In Belgium, dioxin-tainted foods have prompted government recalls. Some environmental groups have expressed concerns about genetically engineered foods. And throughout the United States, authorities have issued warnings about eating wild-caught fish (Table 25-1) due to contamination with one or more toxic compounds.

In June 2000, the National Academy of Sciences, the federal government's premier science advisory organization, issued a report titled "Scientific Frontiers in Developmental Toxicology."[1] Here is a portion of the Executive Summary of that report.

> Of approximately 4 million births per year in the United States, major developmental defects are identified in approximately 120,000 *live-born* (our emphasis) infants. At present, the causes of the majority of developmental defects are not understood. It is known that prenatal exposure to some chemical (e.g., lead, mercury and polychlorinated biphenyls) and physical agents (e.g., radiation) found in the environment can cause developmental defects. Scientists generally agree that approximately 3% of all developmental defects are known to be caused by exposure to toxic chemicals and physical agents, including environmental agents, and almost 25% of all developmental defects might be due to a combination of genetic and environmental factors.

It is no longer controversial that environmental toxins impose a significant cost upon humans, especially fetuses and infants. If we were to assume a minimal cost of each lost human at $1 million (based on awards in liability lawsuits), then the *minimal costs* of such toxins in the environment may exceed $3.6 billion annually in the United States alone and

[1]National Academy of Sciences. National Academy Press, Washington, D.C. http://www.nap.edu/catalog/9871.html and National Academy of Sciences, Washington, D.C. http://www4.nationalacademies.org/news.nsf/0a254cd9b53e0bc585256777004e74d3/85faaeadc1bcdd03852568f1006d5a5b?OpenDocument.

Table 25-1 ■ 1999 Fish Advisories Issued by Contaminant[2]

	1998	1999
Mercury	1,931	2,073
PCBs	679	703
DDT	34	40
Dioxin	55	74
Chlordane	104	101

is likely to be much more. We will examine in the next three issues these three substances identified by the National Academy of Sciences: lead, mercury, and PCBs.

BACKGROUND ON LEAD[3]

Since 1970, emissions of lead have been cut by 98%, attributable mainly to banning lead in gasoline and in paint. Does this mean that lead is no longer a health issue?

Housing for low-income persons remains a major source of lead contamination. For example, in the District of Columbia, low-income children, many of them immigrants, are mainly housed in older buildings. Fifty-six percent of the District's housing stock was built before 1950, and more than 95 percent before 1978. Lead-based paints were used extensively before 1960, but were banned in the late 1970s. In 2000, the DC Department of Health estimated that at least 6.5% of District children had unsafe blood-lead levels, compared to the national average of 4.4 percent. Eighteen years after the District passed a strict law requiring the removal of lead-based paint from residences inhabited by children, lead reportedly continued to poison children. In 1999, the District spent over $1.5 million on lead-poisoned kids. In that year, the last year of report, at least 291 children had lead poisoning, 5 of them serious enough to need hospitalization. Each case costs around $2000 in medical costs and $4000 in special education.

The city also had problems enforcing a 1993 federal law requiring lead screening for all children entering early childhood programs. Portable lead analyzers didn't work, and three city employees assigned to be inspectors were not trained and certified to do the job. In 1999, only 29% of eligible children were screened, and of these 17,845 screenings, 2985 had missing information.

Question 1: Is it reasonable to assume that passage of federal laws ensures that enforcement will correct this problem?

[2]U.S. Environmental Protection Agency, Washington DC (http://www.epa.gov/ost/fish/).

[3]In addition to the sources below, information for this section was obtained from *U.S. News and World Report,* June 19, 2000. Kids at risk: Chemicals in the environment come under scrutiny as the number of childhood learning problems soar (http://www.usnews.com/usnews/issue/000619/poison.htm) and Greater Boston Physicians for Social Responsibility. May 2000. In harm's way: Toxic threats to child development, (http://www.igc.org/psr/).

Here is an example of one of the poisoned children. A 3-year-old girl living in a residence with peeling lead-based paint had blood lead-levels of 64 micrograms per deciliter, more than six times greater than the present federal standard of 10. It took three years of treatment for the child's blood level to fall to 9. During that time, the child experienced "persistent reading and writing problems."

Public schools in the District built before 1978 may themselves be sources of lead poisoning. The city estimates the cost to remediate these schools and to test all eligible children under the age of 6 to be $27.8 million over the first two years, if the project were to be approved.

Question 2: Make a preliminary assessment of a possible connection between lead poisoning and a crisis in primary and secondary education. What additional information would you like to have to address the question more fully?

Finally, some pediatricians have expressed concern that remediation of residences, if improperly done, could actually increase the risk of lead poisoning to children.

LEAD HAZARDS

The current minimum blood level that defines lead poisoning is 10 micrograms of lead per deciliter (1 dL = 100 ml = 0.1 liter) of blood. However, since poisoning may occur at lower levels than presently thought, various federal agencies are considering whether this level should be lowered further[4]

Lead has long been recognized as an extremely hazardous substance, especially to young children, fetuses, and infants; in fact, lead is one of the most toxic natural substances known, affecting virtually every system in the human body. According to the Centers for Disease Control and Prevention, lead poisoning can cause irreversible brain damage and can impair mental functioning. It may also be related to delinquent behavior among juveniles.

A recent report[5] notes that "an estimated 3 to 4 million American preschool children have blood lead levels above 10 micrograms/dl," a level now recognized to be associated with measurable neurological impairment, and as many as 68% of poor, minority children in inner cities may have unsafe lead levels.

Research implicates lead poisoning as a major risk factor in behavioral problems and criminality. One study found that lead poisoning was the strongest predictor of disciplinary problems in school, which in turn was the strongest predictor of arrests between the ages of 7 and 22. Another study, of 501 boys in Edinburgh, Scotland, found that blood lead levels correlated strongly with measures of psychological deviance.

A large-scale study by Herbert Needleman and colleagues,[6] found that children with elevated lead levels but not overt lead poisoning, suffered from reduced IQ, attention deficits, and poor school performance, and that they were seven times as likely as other children to fail to graduate from high school. Many researchers consider high lead levels

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[4]http://emedicine.com.
[5]http://www.igc.org.
[6]http://www.crime-times.org/95c/w95cp7.htm.

to be a risk factor for crime and delinquency, because lead poisoning causes the cognitive problems most strongly linked to criminal behavior: impulsivity, low IQ, hyperactivity, and low frustration tolerance.[7]

Thus, lead can retard mental and physical development and reduce attention span. It can also retard fetal development even at extremely low concentrations. In adults, it can cause irritability, poor muscle coordination, and nerve damage to the sense organs and nerves. Lead poisoning may also cause problems with reproduction, such as a decreased sperm count. And it may increase blood pressure.

In sum, young children, fetuses, infants, and adults with high blood pressure are the most vulnerable to the effects of lead. It is estimated that approximately 930,000 children between the ages of 1 and 5 have seriously elevated blood lead levels.

Here are two reports from the Consumer Product Safety Commission:

1. "The U.S. Consumer Product Safety Commission (CPSC) and Concord Enterprises announces the recall of certain crayons imported from China because of a lead poisoning hazard. CPSC tested the crayons and found hazardous amounts of lead in the yellow and orange color crayons. If a child eats or chews on the crayon, lead poisoning could occur. Therefore, CPSC urges consumers to take the crayons away from children and discard them or return them to the store for a refund. Retailers should stop sale and return the crayons to Concord Enterprises.

The Federal Hazardous Substances Act (FHSA) bans children's products containing hazardous amounts of lead. In addition, the Labeling of Hazardous Art Materials Act amendments to the FHSA require that all art materials be reviewed by a toxicologist for chronic hazards and be labeled appropriately.

Paint and similar surface coatings containing lead have historically been the most commonly recognized sources of lead poisoning among the products within the Commission's jurisdiction. The Commission has, by regulation, banned (1) paint and other similar surface coatings that contain more than 0.06% lead ("lead-containing paint"), (2) toys and other articles intended for use by children that bear lead-containing paint, and (3) furniture articles for consumer use that bear lead-containing paint. In recent years, however, the Commission staff has identified a number of disparate products—some intended for use by children and others simply used in or around the household or in recreation—that presented a risk of lead poisoning from sources other than paint. These products included vinyl miniblinds (Figure 25-1), crayons, figurines used as game pieces, and children's jewelry.[8]

2. After testing and analyzing imported vinyl miniblinds (Figure 25-1), the U.S. Consumer Product Safety Commission (CPSC) has determined that some of these blinds can present a lead poisoning hazard for young children. Twenty-five million non-glossy, vinyl miniblinds that have lead added to stabilize the plastic in the blinds are imported each year from China, Taiwan, Mexico, and Indonesia. CPSC found that over time the plastic deteriorates from exposure to sunlight and heat, to form lead dust on the surface of the blind.

In homes where children ages 6 and younger may be present, CPSC recommends that consumers remove these vinyl miniblinds. Young children, who are most susceptible to lead, can ingest lead by wiping their hands on the blinds and then putting their hands in their mouths. Adults and families with older children generally are not at risk. CPSC found that in some blinds, the levels of lead in the dust was so high that a child ingesting dust from less than one square inch of blind a day for about 15 to 30 days could result in blood levels at or above the 10 microgram per deciliter amount CPSC considers dangerous for young children.

The Arizona and North Carolina Departments of Health first alerted CPSC to the problem of lead in vinyl miniblinds.[9]

The CPSC chided the manufacturers of these lead-containing products, saying that had they acted with prudence and foresight before introducing the products into commerce, they

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[7]Ibid.

[8]http://www.cpsc.gov/cpscpub/prerel/prhtml94/94055.html.

[9]http://www.cpsc.gov/cpscpub/prerel/prhtml96/96150.html.

FIGURE 25-1 Photo of a recalled vinyl miniblind containing lead levels determined by the CPSC to be dangerous to children. (U.S. Consumer Product Safety Commission [www.cpsc.gov])

would not have used lead at all. This in turn would have eliminated both the risk to young children and the costs and other consequences associated with the corrective actions, which will have to be borne by other segments of U.S. society, like the healthcare system.

Question 3: Is the testing of products for toxicity a legitimate role of government? A legitimate role for the federal government?

Question 4: Would you support reducing the size and expense of government by eliminating the CPSC? Why or why not?

Question 5: Should the monitoring of toxic substances be safely left to manufacturers or importers of suspect goods? Justify your conclusion with reasoning/evidence.

LEAD EPIDEMIOLOGY—HOW DANGEROUS IS LEAD AND WHY?

Some pediatricians have concluded that lead poisoning is the most significant chronic childhood illness related to environmental toxins.

Lead poisoning's incidence varies with the child's age and socioeconomic status, a city's population, the child's race, and—very important—the age of the home. Lead is most hazardous to the nation's 24 million children under the age of 6: In fact, one-sixth of children living in cities with over a million people, in homes built before 1946, have elevated lead levels, according to the Center for Disease Control and Prevention.

The effect of lead is complex and beyond the scope of this book; However, the best known effect is that on the production of heme. [Heme, a component of hemoglobin, is a molecule of fundamental importance in animal metabolism. Hemoglobin transports oxygen and exchanges it in the cell for carbon dioxide.] Lead interferes with two critical reactions in the formation of heme. [These reactions occur in mitochondria, structures within cells.] The result is a decrease in heme production.

This means that synthesis of a basic molecule necessary for respiration is inhibited by the presence of lead, and since this reaction occurs at the level of the mitochondria, it has a fundamental importance in human development.

The early symptoms of lead poisoning are easy to confuse with other illnesses: They may include persistent tiredness, irritability, loss of appetite, stomach discomfort, reduced attention span, insomnia, and constipation. Anemia may also be related to lead poisoning. Failure to treat children in the early stages can cause long-term or permanent health damage.

OTHER SOURCES OF LEAD EMISSIONS

Table 25-2 shows sources of lead emissions.

An "average" coal-fired power plant produces 3.5 billion kilowatt-hours in a typical year of operation. One of the by-products is lead: around 114 pounds each year.

Question 6: How much lead is emitted for each kilowatt-hour of electricity produced? Give your answer in micrograms per kilowatt-hour.

In 1970, cars, trucks and buses alone emitted 172,000 tons of lead in their exhaust, and almost 221,000 tons were emitted from all sources. To show you how toxic that lead is, consider the federal standards for lead in the air we breathe: EPA has determined that exposure to more than 1.5 *micro*grams per cubic meter can have adverse health effects—that's only 1.5 millionths of a gram, and there are 28.5 grams in an ounce.

Table 25-2 ■ National Emissions of Lead, 1998.[10]

Source Category	Emissions (short tons[11])
Electric utilities	
Coal	54
Oil	14
Industrial fuel combustion	
Coal	13
Oil	05
Miscellaneous nonresidential fuel combustion	400
Chemical manufacturing	
Lead oxide and pigments	175
Metals Processing	
Nonferrous metals	
Primary lead	628
Secondary lead	505
Lead battery manufacture	117
Ferrous metals	
Steel production	173
Waste Disposal and Recycling	
Incineration	
Municipal waste	75
Other (hospitals, etc.)	546
Non-road Engines	
Aircraft	503

[10] *Statistical Abstract of the U.S.*, 2000.

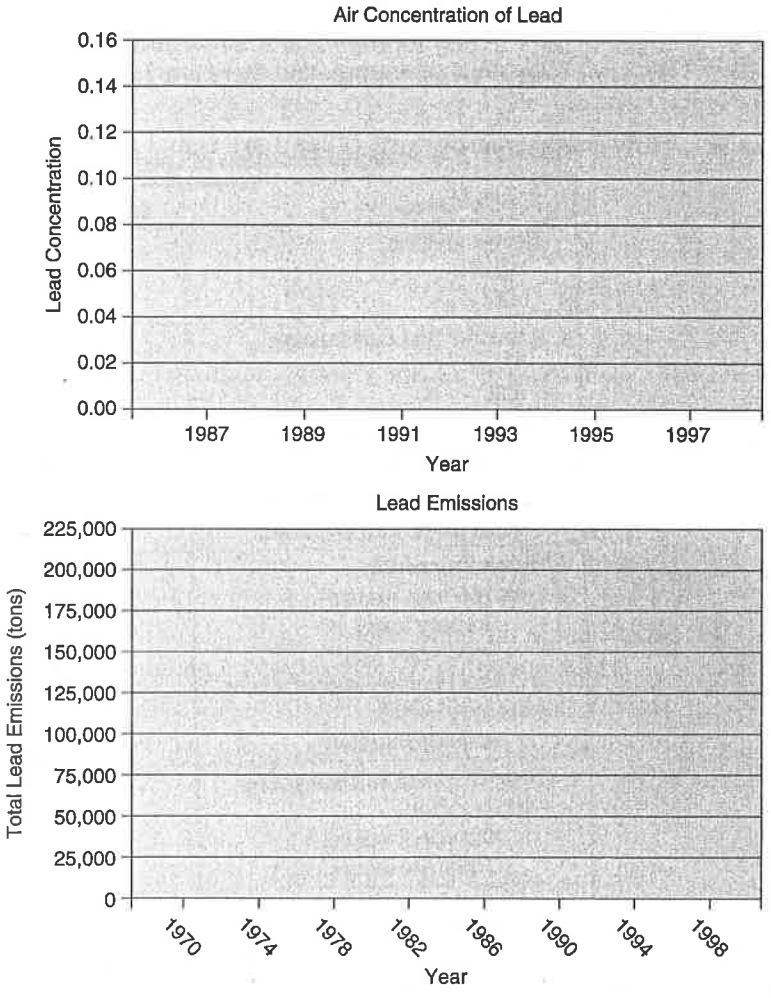
[11] A *short ton* equals 2000 pounds.

Table 25-3 ■ Historical Data on Lead Emissions in the U.S.[12]

# of monitoring stations:	95 (for the entire U.S.!)						
Air quality standard (micrograms/m^3): 1.5							
Date	**1987**	**1990**	**'93**	**'94**	**'95**	**'96**	**'97**
Air concentration of lead, based on 195 stations:	0.16	0.09	0.05	0.05	0.04	0.04	0.04
Date	**1970**	**1975**	**1980**	**1985**	**1990**	**1996**	**1998**
Total lead emitted (tons)	220,869	159,659	74,153	22,890	4,975	3,899	3,073

One of the things we need to know is the actual concentration of lead in the air. Table 25-3 contains lead emissions data.

Question 7: Plot lead emissions and air concentration on the axes below. Are the slopes of the line the same? Note the scales that we used. Try the plot with another pair of scales. Are the slopes sufficiently different to change your conclusions about the relationship?



[12]http://www.census.gov/prod/99pubs/99statab/sec06.pdf.

Question 8: Describe any relationship you observe between the atmospheric lead levels and lead emissions.

One of the objectives of the Clean Air Act of 1970 was to get that lead out of the air, and the Act targeted a major source of lead: the compound *tetraethyl lead,* which had been added to gasoline for years to boost the octane rating. Over the protests of some industry leaders, the law went into effect, and the results have been one of the nation's greatest environmental success stories. By 1975, vehicle emissions of lead were down to 130,000 tons, but the best was yet to come. By 1980, vehicular emissions were down to 60,500 tons, by 1985 to 18,000 tons, by 1990 to only 421 tons, by 1996 to 19 tons, where it has leveled off. Compare this to the amount of lead emitted from other sources in 1998: 2100 tons from metals processing, 503 tons from non-road engines and vehicles, 620 tons from waste disposal and recycling, and only 628 tons a year from primary lead production. In total, slightly under 4000 tons of lead were emitted in 1998, according to the *Statistical Abstract of the United States.*[13]

Question 9: How many micrograms of lead are equal to 4,000 tons?

Since the area of the coterminous United States is about 8×10^{12} meters squared, there is potentially enough lead emitted annually to contaminate the lower 1000 meters of the atmosphere, *assuming* all the lead emitted was airborne and all of it remained in the air. Obviously, this is not the case. So the next question we need to ask is: Where does lead reside if not in the atmosphere?

There are only two places: the soil and the hydrosphere. Lead from old paint, vehicular emissions, incinerators and metal refining, and so on, may collect in dust, and soil, and thus is pervasive and dispersed.

SUMMARY

Let's now consider the impact of lead on animals, specifically humans. Before lead came into industrial use, human blood contained approximately 0.5 micrograms of lead in each tenth of a liter [deciliter] of blood (expressed in scientific shorthand as 0.5 micrograms per deciliter: recall that 1 microgram is a millionth of a gram and there are 28+ grams per

[13]Ibid.

ounce; a liter is about a quart; thus a deciliter is about half a cup.) Therefore, the "natural background level" of lead in human blood is around 0.5 micrograms per deciliter.[14]

The following information is from a report entitled "The President's Task Force on Environmental Health Risks and Safety Risks to Children" available from the Center for Disease Control's website[15] and from Rachel's *Hazardous Waste News,* which summarizes a U.S. government report.[16]

- A child is estimated to lose two IQ points for each 10 mcg/dl increase in blood lead level.
- Children's hearing may be impaired by blood-lead levels below 10 mcg per deciliter and hearing problems can exacerbate learning disabilities.
- Nearly one million children living in the United States have blood lead levels high enough to impair their ability to think, concentrate, and learn. But this number has been significantly reduced from the 1980s: Then, among U.S. children 5 years old or younger, 63.3% had between 10 and 19 micrograms per deciliter; 20.5% had 20 to 29 micrograms per deciliter; 3.5% had 30 to 39 micrograms per deciliter; and 0.5% had 40 or more. Thus, the proportion of children aged 1 to 6 with lead poisoning fell to 4.4% over the period 1991 to 1994, an 80% decline from 1976–1980. But is this good enough?

Question 10: How many lead atoms would be in each liter of the blood of a child at a concentration of 10 mcg/dl?

Finally, consider this: The federal Agency for Toxic Substances and Disease Registry (ATSDR) concluded: "Lead-induced reductions in IQ not only place the individual at a disadvantage, but also eventually place the nation at a collective disadvantage in an increasingly competitive, technical, and cognition-intensive world economy." (quoted in Rachel's as cited above[17]). Clearly, lead poisoning affects society at large, and not just the individual and her or his family.

FOR FURTHER STUDY

- In 1996 the Commission had 487 employees and a budget of around $46 million. Go to the CPSC website, www.cpsc.gov, and determine whether Americans are getting sufficient value for this expense. Justify your answer with evidence.
- *Lead, housing and the educational system:* Citizens of Arlington County, Virginia are, like most Americans, extremely concerned about the success of their public schools. Parents and taxpayers routinely decry examples of disruptive, aggressive, hyperactive, or confrontational behavior by school children toward their peers as

[14]http://rachel.enviroweb.org/rhwn213.htm.
[15]http://www.cdc.gov/washington/legislative/05022000.htm.
[16]http://rachel.enviroweb.org/rhwn213.htm.
[17]Ibid.

well as teachers, but rarely is the possibility that lead poisoning may contribute to such behavior discussed (see above).

Analyze the following statistics from Arlington County, Virginia[18]

Size:	25.8 square miles
Population density	7252/square mile

Housing Stock According To Year Built

Year Built	Total Units (1990)
1989 to March 1990	2,324
1985 to 1988	5,518
1980 to 1984	3,924
1970 to 1979	7,914
1960 to 1969	15,868
1950 to 1959	18,764
1940 to 1949	19,832
Before 1940	10,703
Total	84,847

In what type of housing do you conclude the poor live—rental or owner-occupied housing? Could housing choice be contributing to behavioral problems in schools? What other information would you like to have to answer the question?

[18]www.census.gov, and Lead paint in apartments costs landlords $540,000. S. Chan, *Washington Post,* 2000, October 5, B5.