

# Lead Poisoning

Carol A. Pertowski, M.D.<sup>1</sup>

## PUBLIC HEALTH IMPORTANCE

Lead poisoning is one of the most common environmental health problems affecting young children. The Environmental Protection Agency estimates that in 1990, 3 million children had blood-lead (PbB) levels high enough ( $\geq 10$   $\mu\text{g}/\text{dL}$ ) to cause adverse health effects (1). Health effects from lead exposure vary with the PbB level. Severe neurologic problems, such as coma and seizures, and death have been associated with blood-lead levels of  $\geq 80$   $\mu\text{g}/\text{dL}$  (2). Renal damage and decreased hematopoiesis have occurred among patients with PbB levels of 40–80  $\mu\text{g}/\text{dL}$  (2). Adverse health effects can also occur at low levels, however. PbB levels as low as 10  $\mu\text{g}/\text{dL}$  have been associated with decreased intelligence and impaired neurobehavioral development (3,4). Most children with elevated PbB levels are asymptomatic (5), and lead exposure is usually a diagnosis based on laboratory findings.

Childhood lead poisoning is a preventable disease. Most childhood lead exposure in the United States results from exposure to household lead-based paint or dust from this paint (6). In 1989–1990, the U.S. Department of Housing and Urban Development evaluated the extent of lead paint hazards in the nation's housing stock (7). The results of this survey suggest that 3.8 million housing units containing either lead-based paint in deteriorated condition or high levels of lead in dust are occupied by families with children <7 years of age. Also preventable are exposures to lead through drinking water, soil, traditional or folk medicines, fishing sinkers, bullets, materials used to make ceramics and stained glass, and **take-home** exposure from household members occupationally ex-

posed to lead. All children are at risk for lead exposure; young children living in deteriorated housing in inner cities are at the highest risk (6).

In October 1991, CDC revised its policy statement on preventing lead exposure among young children (6). In this statement, CDC lowered the PbB level of concern from 25 to 10  $\mu\text{g}/\text{dL}$ ; recommended the phasing in of **virtually universal screening** (i.e., screening of all young children except in communities where large numbers or percentages of children were screened and did not have elevated PbB levels); emphasized the importance of primary prevention (i.e., identification and remediation of lead hazards before a child's PbB level is elevated); and identified PbB measurement as the screening test of choice. The lead statement also included an approach for investigating sources of lead, remediating lead hazards, and conducting medical follow-up based on an affected child's PbB level.

In February 1991, the Department of Health and Human Services announced its *Strategic Plan for the Elimination of Childhood Lead Poisoning* (8). Surveillance of lead exposure is one of the key program components of the *Strategic Plan*. Surveillance is needed to identify children at highest risk for lead exposure, target interventions, and track our progress in

<sup>1</sup> Division of Environmental Hazards and Health Effects  
National Center for Environmental Health  
Centers for Disease Control and Prevention  
Atlanta, Georgia

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eliminating lead exposure. To develop surveillance systems at the state level, programs may need to integrate information from several sources: childhood lead poisoning prevention programs at the state and local levels, public and private laboratories, and health, environment, and housing agencies.

Lead exposure among children is a worldwide health issue, although the predominant sources of lead in other parts of the world may differ from those in the United States. Increased lead levels in air and soil have been measured in areas such as Eastern Europe where environmental controls of industrial sources have not been fully implemented. Lead contamination from cottage industries, such as battery repair shops, have also been associated with elevated PbB levels among children (9). In countries where leaded gasoline is used, automobile emissions may contribute to elevated PbB levels among children (10,11). Other sources of lead include improperly fired or unfired lead-glazed pottery (12,13) and lead in canned foods (13). For additional information about related topics and surveillance activities, see the Pediatric Nutrition chapter.

## HISTORY OF DATA COLLECTION

During the 1970s and early 1980s, CDC funded childhood lead poisoning prevention projects in state and local health departments, where program staff hand-tallied the number of children screened for lead exposure and the number of children with elevated PbB levels. During 1981, 62 childhood lead poisoning prevention programs reported screening >500,000 children, >18,000 of whom had PbB levels above 30  $\mu\text{g}/\text{dL}$ , the CDC level of concern at the time (14). The reporting process was difficult, however, and children tested several times a year may have been counted more than once.

In 1981, funding for childhood lead poisoning prevention programs was folded into CDC's Maternal and Child Health Services Block Grants. Each state was allowed to decide how it would allocate resources provided by these grants. The federal reporting requirements for

childhood lead levels were eliminated, and the surveillance system was discontinued.

Less than a decade later, the Lead Contamination Control Act of 1988 authorized money for CDC to administer a childhood lead poisoning prevention grant program. Most of the money is provided as grants to state and local agencies to screen children for elevated PbB levels, to assure medical and environmental follow-up, and to conduct educational programs about lead exposure in communities with children who have elevated PbB levels.

Recently, CDC collaborated with the Council of State and Territorial Epidemiologists (CSTE) to develop a national surveillance system for monitoring PbB levels among children. In 1990, CSTE approved a position statement recommending that states require that elevated PbB levels be reported to state health departments and establish surveillance for elevated PbB levels in all age-groups.

At the state or local level, the primary source of data for surveillance is usually the childhood lead poisoning prevention program. These programs are responsible for screening children, ensuring that children with elevated PbB levels receive appropriate medical follow-up and environmental management, and for collecting, managing, and reporting data. The collaboration and coordination of activities by staffs at the health department, housing authority, and environmental agencies are crucial for assuring complete medical and environmental management of children with elevated PbB levels and for carrying out primary prevention of lead exposure. Because young children are at an increased risk for lead exposure, screening programs focus on children <6 years of age.

Information from public health screening programs is a valuable resource for surveillance data; however, these data have limitations. First, data from these programs are restricted to populations targeted by the program. Because prevention programs usually target children thought to be at a high risk for elevated PbB levels, the population screened may not be representative of the entire population. Data from

these programs are inadequate to assess population rates or to estimate a community's burden from lead exposure, and they are of limited use in monitoring trends. Second, although many state and local agencies gather data from environmental investigations and medical management of children with elevated PbB levels, in some states these data are not organized into a single database that can be used to track trends over time.

The National Health and Nutrition Examination Surveys serve as another source of national data for estimating the number of children with elevated PbB levels. Although these surveys provide national estimates of the prevalence of elevated PbB levels among children, they do not provide information at the state or local level. Also, these surveys do not directly measure incidence, and the data cannot be used to follow short-term trends.

Other sources of data that can provide supplemental information on childhood lead exposure are the National Health Interview Survey, Injury Control and Risk Survey, National Hospital Discharge Survey, and surveys conducted by state health departments.

The national surveillance system for PbB levels among children is based on systems developed and maintained at the state level. One key component for surveillance at the state level is a law mandating that laboratories report PbB levels to state health departments. A 1989 survey examining state and territorial laws for reporting childhood PbB levels indicated that a majority of jurisdictions required the reporting of elevated PbB levels among children but that the PbB concentrations that had to be reported varied (15). Of the 29 jurisdictions with mandatory reporting requirements, only 2 states mandated the reporting of all test results, regardless of the PbB value. The majority of the jurisdictions required the reporting of PbB values of  $\geq 25$   $\mu\text{g}/\text{dL}$ —the level defining childhood lead poisoning at the time of the survey. Of the jurisdictions that specified age-groups, all required the reporting of elevated PbB levels among children  $\geq 5$  years old. The mechanism of reporting also varied among these 29 jurisdictions: 24 required private laboratories to report; 22 re-

quired public laboratories to report; and 13 required both in-state and out-of-state laboratories to report. In addition, 23 jurisdictions required physicians to report, and 11 required screening programs to report. Since the survey was conducted, several states have modified their reporting requirements.

In September 1992, CDC awarded cooperative agreement funds to eight state health departments to help them in carrying out PbB surveillance activities. The goals of the national childhood PbB surveillance program are to increase the number of state health departments with surveillance systems for PbB levels among children; build the capacity of states and territories to conduct laboratory-based surveillance of PbB levels; use data from these systems to establish a national surveillance system; disseminate data on the extent of elevated PbB levels among children to government agencies, researchers, and medical care providers; and direct intervention efforts to reduce environmental lead exposure.

## CDC SURVEILLANCE ACTIVITIES

CDC's National Center for Environmental Health is responsible for developing and maintaining the national surveillance system for childhood lead levels. This system is based on data collected by state health departments. For national surveillance, a child is considered to meet the case definition if any venous sample contains a lead level of  $\geq 10$   $\mu\text{g}/\text{dL}$  or if two capillary samples taken within 12 weeks of each other both contain levels of  $\geq 10$   $\mu\text{g}/\text{dL}$ . The system is based on laboratory reporting, which may simplify and help achieve completeness of reporting (16).

In conjunction with the eight states that received 1992 cooperative agreement funds to develop surveillance systems, CDC developed new data fields for the national surveillance system of children with PbB levels (Table 1) and an approach for data management and transfer. The surveillance data can be extracted from laboratory reports and from information collected by health departments as part of the medical and environmental management of a child with elevated PbB levels. To organize data from environmental and medical follow-up of a child

with elevated PbB levels, many state and local health departments use computer software such as the System for Tracking Elevated Lead Levels and Remediation (STELLAR), a public domain program developed by CDC (17). CDC is developing computer programs that will allow health departments to directly import data from laboratories into STELLAR and to extract surveillance data from the STELLAR database.

The degree and use of technology, number of children with elevated PbB levels, and approaches to case-management vary from state to state; however, a state surveillance system for children <16 years of age who have elevated PbB levels should include several basic components (Table 2). This database will allow states to describe children aged <16 years with elevated PbB levels over time, by person, place, and likely source of exposure. Additional information on funding sources for screening, type of screening program, medical treatment, and environmental follow-up of children with elevated PbB levels will be available.

The database will also provide information to calculate case-rates among children aged <6 years who receive PbB tests. Data on all children aged <6 years who have been tested for lead exposure, regardless of the test result, may be maintained in the same database as that for children with elevated PbB levels. These data will provide denominator estimates for calculating rates of elevated PbB levels among children in this age-group who have been tested. Data on children aged <6 years without elevated PbB levels are limited to laboratory slip information, because these children do not receive medical or environmental follow-up. The number of children aged <6 years may be large, and limited resources may prevent states from collecting data for a full year. Therefore, data on these children may be collected for less than a full year and be extrapolated to yearly estimates. To maximize representativeness, states should include data from all quarters.

States transfer quarterly data by using CDC WONDER/PC, a public-domain software system developed by CDC for public health programs. This system also links sites together via

an electronic mail system and will soon allow state surveillance programs to perform a set of basic analyses on their data.

## GENERAL FINDINGS

The surveillance system is currently being developed, and no national data are available. When these data are available, they will have numerous useful applications. First, a descriptive picture of children with elevated PbB levels will be provided. The importance of paint and nonpaint sources can then be determined, and clusters of children with elevated PbB levels can be identified. Second, an estimate of children newly identified as having elevated PbB levels (prevalence of new cases at screening) and an estimate of all children with elevated levels (prevalence of all cases) among children tested can be calculated.

## INTERPRETATION ISSUES

### Advantages of the System

Advantages of the system include its usefulness and relative simplicity. The case definition is simple because it requires only the reporting of elevated PbB levels. The use of laboratory-based reporting will simplify the system. Automated data transfer will facilitate management of the large numbers of PbB reports. The surveillance system also does not require the collection of data beyond the information usually obtained during the investigation and treatment of a child with an elevated PbB level.

State and local health departments will be able to use information from this system for planning or modifying prevention programs. The data also will be useful for evaluating the cost-effectiveness of specific screening activities such as door-to-door screening. Collecting information on both the number of children with elevated PbB levels and the number tested will allow states to identify neighborhoods or towns with children **at high risk** or those **not at risk** for elevated PbB levels. Interventions or screening programs can then be directed to high-risk groups.

**TABLE 1. Proposed data fields for the national surveillance of children with elevated blood-lead levels — Centers for Disease Control and Prevention, 1993**

<b>VARIABLES SUBMITTED ON LABORATORY SLIP*</b>		
Child ID Number	Date of birth	Residence with peeling, chipping, or flaking paint
Sex	Race	Date child moved to present residence
Ethnicity	Address ID	Residence renovated
City	County	Date renovation started
State	ZIP code	Date renovation completed
Medicaid enrolled		
Type of sample (venous or capillary)	Results ( $\mu\text{g}/\text{dL}$ )	
Date sample drawn	Date sample analyzed by lab	
Laboratory type (public health or commercial)		<b>Environmental investigation information</b> (Highest value obtained)
		Location (current or former residence, child care facility, residence of relative)
<b>DATA FROM CASE INVESTIGATION†</b>		
<b>Program data</b>		
Date sample received by state health department		Dust samples in $\mu\text{g}/\text{ft}^2$ or ppm (floors, window sills, window wells)
Child previously with elevated blood-lead level		X-ray fluorescence reading
Type of provider ordering test (fixed site specific to lead, door-to-door program, other screening program such as WIC, private health-care provider)		Paint chip analysis
Reason for test (screening an asymptomatic child, confirmatory test after an elevated value by finger-stick, follow-up of confirmed elevated level, clinical suspicion of lead poisoning)		Soil sample analysis
Funding source (public, including Medicaid, state or local programs; private insurance; self-pay)		Water sample analysis
		<b>Nonpaint hazards</b>
<b>Treatment data</b>		Traditional medicines
Child received chelation therapy		Household member with occupation using lead (e.g., welder, battery repair shop operator)
Type of chelation therapy (inpatient, outpatient, both)		Child with occupation involving lead exposure
Source of funding for chelation therapy		Household member with hobby using lead (stained glass, pottery/ceramics, making bullets or fish sinkers, using fire-arms or artist paints)
<b>Paint hazard data</b>		
Age of child's residence		Improperly fired or imported pottery used for eating, cooking, or food storage
Ownership of child's residence (private or public, owned or rented)		Industrial facility near home

\* Information collected on all blood tests, regardless of lead level.

† Information collected for children with lead levels above the action level for environmental and medical investigation defined by the state. The action levels vary from state to state.

## Limitations of the System

One inherent limitation of the system results from reliance on information reported by laboratories because the data are often incomplete. Assuring the reporting of all PbB tests, especially

those submitted to private or out-of-state laboratories, may be difficult. The data on laboratory reports are a vital component of the surveillance database; information on children with PbB levels of 10–19  $\mu\text{g}/\text{dL}$  and  $<10 \mu\text{g}/\text{dL}$  may be limited to data provided on the laboratory slip.

**TABLE 2. Components of a state surveillance system for children aged <16 years with elevated blood-lead levels**

<p>1. A law or regulation mandating the reporting of blood-lead (PbB) levels.</p>	<p>An indication of whether the child previously had a PbB level of <math>\geq 10</math> <math>\mu\text{g/dL}</math> is also added to the data set.</p>
<p>Reports are submitted by both private and public laboratories.</p>	<p>A child remains in the database only for the calendar year in which the elevated PbB level was drawn.</p>
<p>Reports contain sufficient demographic information to allow states to identify the child and assure appropriate follow-up.</p>	<p>4. Estimates of children tested.</p> <p>Data on all children aged &lt;6 years who have been tested for lead, regardless of test result, may also be maintained in this database.</p>
<p>2. Development of a state database of information children with elevated PbB levels (<math>\geq 10</math> <math>\mu\text{g/dL}</math>)</p>	<p>These data will provide denominator estimates for calculating rates of elevated PbB levels among children aged &lt;6 years who have been tested for lead exposure.</p>
<p>Data on children are entered into the database with the first report of a PbB level of <math>\geq 10</math> <math>\mu\text{g/dL}</math>.</p>	<p>5. Data transmission and analysis.</p> <p>Identifying information is removed, and a unique number is assigned to each child.</p> <p>The surveillance database is transmitted quarterly to CDC.<sup>†</sup></p>
<p>Subsequent blood test results on children already in the database are added to the children's files.</p>	<p>The final database for a calendar year is compiled by CDC from data received by March 31 of the following year.</p>
<p>States add to the data set the type of laboratory (i.e., public or private) performing the test, the date the sample was received by the health department, and the data from the laboratory slip (Table 1).</p>	<p>States perform quarterly analyses and release annual reports of descriptive data; they generate yearly case-rates among tested populations.</p>
<p>States coordinate the collection of information from environmental and medical case-management (Table 1) and add this information to the database.</p>	<p>6. Use of automated data transfer.</p> <p>To facilitate the management of large amounts of data, programs focus on the use of automated data transfer whenever possible.</p>
<p>3. An age-dependent approach to data management.*</p> <p>For children aged &lt;6 years:</p>	
<p>A child remains in the database until the child's 6th birthday.</p>	
<p>For children aged 6–16 years:</p>	

\* Because screening programs focus on children aged <6 years, the data for these children are obtained in a manner different from that for children aged  $\geq 6$  years.

<sup>†</sup> States with a large number of children may wish to transfer data more frequently than quarterly.

To facilitate reporting, CDC is working with CSTE and the Association of State and Territorial Public Health Laboratory Directors to establish core variables for reporting from public and private laboratories.

Another potential limitation to initiating a state surveillance activity is the time needed to establish the system. To promote efficient use of time and resources, states should avoid duplicating efforts conducted during case-management activities and use computerized data management

and transfer. However, organizing a state surveillance system may require pulling data together from several childhood lead poisoning prevention programs within the state and assuring complete reporting of data. Assuring complete data reporting may involve educational programs for physicians and for laboratory staff. Once the system is established, states must provide personnel to maintain the surveillance database and to analyze and disseminate the data.

In addition, we must consider the limitations related to the representativeness of the data. Currently, many children are tested in screening programs. Because screening programs usually focus on children at high risk, the population of children tested in the state and the population with elevated PbB levels may not be representative of all children in the age-group of interest. The number and demographic characteristics of children tested by private health-care providers and screening programs may also reflect awareness campaigns by state and local health departments. The amount and type of information on children with elevated PbB levels may not be comparable across sites because the approach to medical follow-up and environmental management at the state and local levels varies with the PbB value and the resources of the agency. When interpreting the data, we must take these limitations into account.

Another limitation is the potential for false negatives. Screening for elevated PbB levels can be conducted on samples obtained from either a venipuncture or a finger-stick (capillary sample). Although **one** elevated PbB level from a sample obtained by venipuncture defines a case, **two** finger-stick specimens taken within 12 weeks of each other with levels of  $>10 \mu\text{g}/\text{dL}$  are needed to define a case. Because sequential finger-stick samples with elevated PbB levels taken within 12 weeks of each other may not be available, some children with persistently elevated PbB levels may be incorrectly classified as not meeting the case definition.

## EXAMPLES OF USING DATA

Although data collection for the national surveillance system has just begun, several states have already used their surveillance data to develop legislation supporting lead poisoning prevention activities, obtain funding, identify risk groups, and target screening and prevention activities.

### California

In 1986, California established a Childhood Lead Poisoning Prevention Program (CLPPP) and reporting requirements for a laboratory-based surveillance system for all persons with PbB levels  $\geq 25 \mu\text{g}/\text{dL}$ . The surveillance system documented an increasing number of children with elevated PbB levels in 1989 and 1990. In response to this increase, the legislature in 1991 passed additional laws supporting childhood lead poisoning prevention efforts. One law mandated that all children in California be screened according to standards set by regulations that are at least as stringent as the CDC guidelines and authorized the CLPPP to change the reporting requirements for PbB levels as necessary. In addition, under the Child Health and Disability Prevention Program, physicians providing health care to low-income children are required to provide PbB screening to all children who attend publicly funded well-child day care facilities.

Data from the surveillance system have shown that children living outside metropolitan areas also have elevated PbB levels. The California CLPPP has used this information to educate health care providers about the need to screen children not usually thought to be at risk for lead exposure. In addition to paint sources of lead, the system has shown the importance of nonpaint sources such as traditional medicines (18) and ceramic ware. Because the system currently collects only reports of elevated PbB levels—rather than reports of all PbB levels measured—rates of elevated PbB levels among

children cannot be calculated. The California CLPPP is adapting its reporting requirement and surveillance system to collect reports of all PbB levels.

## Iowa

Since September 1992, Iowa has used both laboratory-based and physician reporting for the surveillance of all PbB levels among children. Data from the surveillance system suggest that children in both rural and urban parts of the state have elevated PbB levels. Because the surveillance system collects reports of all PbB levels, the Iowa CLPPP has been able to calculate rates of elevated PbB levels among all children tested for lead exposure. The rates of children with elevated PbB levels in many small towns and rural areas are higher than rates in some urban regions of the state. These findings—and data suggesting that many children screened by private health-care providers have elevated PbB levels—are being used to educate physicians about the need to screen all children for lead.

The state and county health departments have used data from the surveillance system to build communitywide coalitions and to develop and fund local CLPPPs. The state CLPPP also used these data to inform legislators of the need for authority to inspect and require remediation of lead hazards in the residences of children with elevated PbB levels and to develop a contractor certification program to assure that lead hazards are remediated properly.

## Massachusetts

In a study using 1988 data from the Massachusetts lead poisoning prevention program, researchers found that only 43% of children aged 13–24 months and 29% of children aged 25–36 months were screened for elevated PbB levels (19). They also found that 30% of children with elevated PbB levels lived in rural or suburban communities. The screening schedule subsequently adopted by Massachusetts requires that all children be assessed for the risk of exposure to lead and be screened for elevated PbB levels periodically during early childhood. In 1990, Massachusetts established a laboratory-

based surveillance system that requires reporting of PbB levels among children. Data from the surveillance system are used to evaluate state programs and to target screening activities.

## FUTURE ISSUES

In 1990, an estimated 3 million children aged 6 months through 5 years had PbB levels exceeding 10 µg/dL (1). The U.S. Department of Health and Human Services has defined the year 2000 objective for childhood lead exposure as “reducing the prevalence of PbB levels exceeding 15 µg/dL and 25 µg/dL among children aged 6 months through 5 years to no more than 500,000 and zero, respectively” (20). For inner-city black children, special targets have been set at 75,000 children with levels of 15–25 µg/dL and no children with levels above 25 µg/dL.

During the next few years, a major challenge to surveillance will be to collect data from portable blood lead analyzers. Equipment that will allow us to analyze blood samples in the field may soon be available. Analysis in the field may facilitate the notification of parents about their child's PbB test results and allow us to collect more accurate demographic data. However, assuring that all test results are reported to state health departments will require innovative approaches.

We also can expect an increased use of automated data transfer and improvements in the scope and quality of data collected. Continued progress in the development and use of computerized systems will enhance surveillance systems at the local, state, and national levels. Automated data transfer is a crucial time-saving measure, especially in programs where different agencies maintain separate databases and are responsible for different components of case-management. For example, the use of electronic data transfer systems such as the Public Health Laboratory Information System will facilitate the reporting of PbB test results from laboratories to state or local health departments. Advancements in the CDC WONDER/PC system will simplify data analysis by expanding the

number and type of data analyses available to state surveillance programs as menu-driven programs.

Over the next few years, more states will be submitting data to the national surveillance system, thus improving the representativeness of the data. At the state level, data quality will likely improve as reporting is standardized (e.g., as laboratories begin using a set of core variables). With time, state surveillance programs will be better able to obtain data from laboratories performing PbB analyses and to identify and complete missing risk factor and environmental information.

Achieving the year 2000 objective for reducing childhood lead exposure requires an increased use of primary prevention measures. Improvements in the scope and quality of the surveillance database will provide a clearer picture of the extent and determinants of childhood lead exposure in the United States and will help programs allocate resources and coordinate primary prevention efforts.

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