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NBS TECHNICAL NOTE 759

The NBS Lead Paint Poisoning Project: Housing and Other Aspects

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The NBS Lead Paint Poisoning Project: Housing and Other Aspects

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Harvey W. Berger

The National Bureau of Standards is providing technical support required by the Department of Housing and Urban Development to carry out its research responsibilities under PL 91-695, The Lead Based Paint Poisoning Prevention Act. The program at NBS has involved three major areas of research: (1) an estimation of the numbers of children at risk and with excessive body burdens of lead and the geographical distribution of those children; (2) the capabilities and characteristics of analytical methods for the detection of lead in paint and other building materials and (3) the identification and evaluation of materials, techniques and systems for removing or eliminating the lead paint hazard from housing. This paper is a brief presentation of the activities and conclusions of NBS in the areas listed above.

Key words: Hazard elimination; lead analysis; lead paint; lead poisoning.

1. Introduction

There are 17 million children aged one to six living in our nation's cities. Two and a half million of them live in old, dilapidated housing built before 1940 [1]. They are the ones who are most acutely exposed to the dangers of lead paint poisoning. Current medical evidence indicates

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that at least 90% of the children that have lead poisoning have eaten paint containing lead [2]. There is little doubt that a major cause of this widespread poisoning is the availability and accessibility of old lead paint.

The cities of Baltimore, New York, Chicago, Philadelphia and New Haven have had lead poisoning control programs in operation for many years. As a result of their activities and the efforts of community based organizations, the scope and severity of lead paint poisoning received increasing attention and in 1970 Congressional hearings were held on this problem [3,4].

In January 1971 the Lead Based Paint Poisoning Prevention Act, PL 91-695, was signed into law by President Nixon. That law defined three major areas of responsibility for the Department of Health, Education and Welfare and one major area of responsibility for the Department of Housing and Urban Development (HUD). Under Title III, HUD was directed to carry out a research and demonstration program to determine the nature and extent of the problem of lead based paint poisoning and to identify and evaluate methods for the elimination of the problem.

The Department of Housing and Urban Development and the Department of Commerce have an inter-agency agreement [5] establishing the National Bureau of Standards (NBS) as the center of technical support for HUD in the area of building research and housing technology. In order to fulfill its mission on lead paint poisoning, HUD called upon NBS to provide technical assistance in carrying out its research programs. The NBS

Lead Paint Poisoning Project was established within the Building Research Division (now the Center for Building Technology). That division had the responsibility for overall program coordination and planning in addition to the task of identifying and evaluating methods and materials for the elimination of the hazard from housing. The Analytical Chemistry Division was assigned the task of identifying and evaluating methods for the detection and measurement of lead in building materials, and the Applied Mathematics and Technical Analysis Divisions were called upon to estimate the magnitude of the problem and to describe its nature and geographical distribution.

2. National Estimates of Lead Paint Poisoning

A major research effort carried out by the Applied Mathematics and Technical Analysis Divisions was the development of a mathematical model to provide estimates of the national extent of lead paint poisoning. Several factors may contribute to the incidence of this disease. The characteristics of housing such as its age; condition; vacancy rate; whether it is owned or rented; whether it is single or multiple unit and the characteristics of the occupants of that housing: the age of the children; crowding; mobility; income; educational level and other factors have been considered and evaluated. It appears, however, that there are only two factors that are essential for the estimation of lead paint poisoning incidence. They are: dilapidated housing, and occupancy of that housing by children aged 6 or less.

The mathematical model shown below has been used to estimate the number of children (N) in urban areas who have the elevated blood lead levels (EBL's) that are indicative of excessive body burdens of lead. D/H is the fraction of urban housing in the United States which is dilapidated; it essentially represents housing built before 1940. The factor f is the fraction of all children aged 1 to 6 who live in such housing and are likely to have elevated blood lead levels. C is the total number of children aged 1 to 6 living in urban areas.

$$N = C \times \frac{D}{H} \times f$$

From summing the results of the above equation it is estimated that more than one half million children have elevated blood lead levels. This estimate is probably low because the model and estimate are based on Standard Metropolitan Statistical Areas (SMSA's) which represent only urban areas.

3. Detection of Lead in Paint

The second area of research at NBS has been the identification and evaluation of analytical methods for the detection and measurement of the lead content of paints. Of the hundreds of chemical methods for the analysis of lead only a few are applicable to the special problems encountered in the analysis of old embrittled paint films. The methods studied by the Analytical Chemistry Division were spectrophotometry using the dithizone procedure, atomic absorption, X-ray fluorescence using both laboratory and portable instruments, electrochemical techniques and spot and flame tests. Flame aspirated atomic absorption is a favored technique used in several cities. It is extremely accurate and reliable, but requires costly and time consuming preparation of the paint film before the analysis can be performed. A chemist aided by technicians can analyze 50 to 100 paint chips a day using one atomic absorption instrument. If 20-40 paint samples are taken from each dwelling as is required in some communities, only 2 to 3 dwellings would be screened per day at that rate.

Portable X-ray fluorescence instruments have been used for some time, in several cities, for detecting lead paint on-site. This technique is non-destructive and gives an immediate indication of the presence of lead. The limit of detection of most of the portable X-ray fluorescence analyzers is 1 mg/cm^2 [6]. If one were to assume that a single layer of paint weighs 10 mg/cm^2 the detection limit would then be equivalent to 10% lead in that single layer. If there were 10 layers of paint in a paint chip then the 1 mg/cm^2 detection limit would be equivalent to 1% lead. The analyzers can be an effective tool for the rapid screening of housing for relatively high contents of lead. Surfaces containing 2 or more mg/cm^2 of lead can quite reliably be detected and identified as presenting the greatest risk on a priority basis. There still are needs however for rapid, sensitive, nondestructive portable techniques for the detection of lead in paint.

A standard paint sample has been prepared for use in calibrating instruments used in lead measurement and for assisting laboratories to determine their own capabilities for paint analysis. The reference material is based on authentic lead paint chips obtained from the de-leaded walls of houses in several cities. The powdered samples have been analyzed and certified and are available to public and private laboratories [7].

4. The Housing Problem

The Building Research Division's activities were concentrated in two major areas. The first involved a study of the history and extent of usage of leaded paints in housing. The second was concerned with an evaluation of methods that are currently available for the elimination of the lead paint problem. The first area is obviously quite important because of the extent of lead poisoning that has been traced to the ingestion of lead paint.

Before the advent of modern protective coatings, houses were painted with white-wash and calcimine--both of which were non-leaded materials. Lead pigments were the first pigments produced on a large commercial scale when the paint industry began its growth in the early 1900's. Up through the 20's and 30's the favorite paint of the housepainter was pure white lead paste mixed with enough linseed oil to make it spreadable. In the 30's factory mixed paints began to take greater shares of the market, and lead pigments were replaced gradually with zinc and other white opacifiers. In the 40's, titanium dioxide became available and because of the growth in popularity of latex paints it became the most commonly used pigment for residential coatings. There was no regulation of the use of leaded house paints until 1955, when the paint industry adopted a voluntary standard [8] proposed by the American Standards Association (now the American National Standards Institute) which limited the lead content in paint for interior uses to no more than one percent by weight of the non-volatile solids.

In recent years, a few cities have passed laws prohibiting the sale and use of interior paints containing more than 1% Pb. Until PL 91-695 was passed in 1971, however, there was no nationwide law limiting the use and/or sale of leaded paints. The use of titanium dioxide as a pigment has increased markedly since its introduction, but it did not replace white lead pigments immediately. While the production of lead pigments has declined steadily since the mid 1940's, they have not yet been completely removed from the market.

By analyzing the limited paint pigment and paint production data available, a determination was made of the extent of both leaded and non-leaded paint production in the United States over a period of years as shown in figure 1. The analysis of leaded paints was limited to those containing white lead and leaded zinc oxide as major pigments because it was not possible to determine the usage of lead coloring pigments in residential paints. Therefore, the estimates for leaded paint production are moderately low. In those early years when the percentage of lead paint production was high, most of the paint intended for residential use was leaded, and a significant percentage of the house paint produced after 1950 also contained lead.

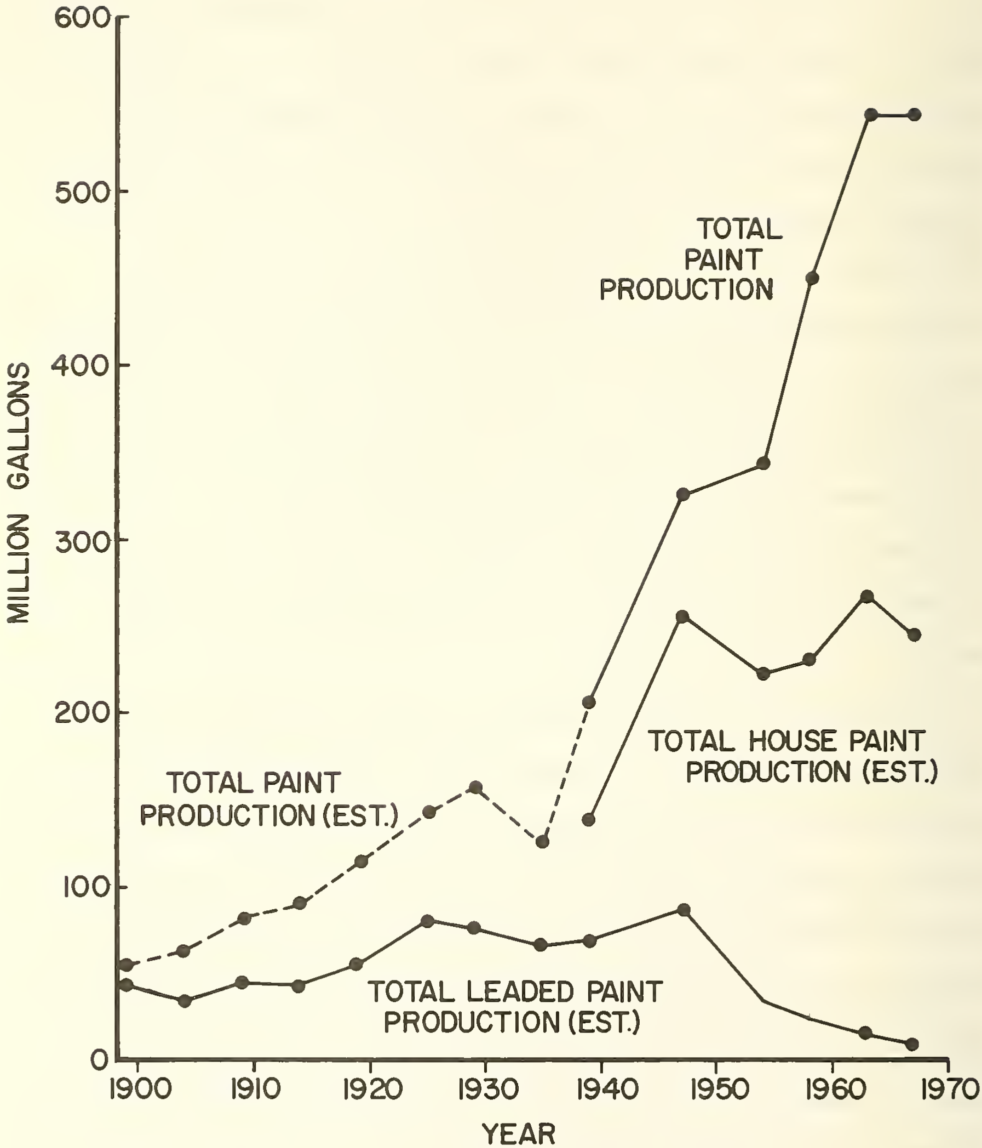

Figure 1. Paint Production Graph

Using paint production information, the numbers of dwelling units that could have been painted with leaded and nonleaded paints were calculated by multiplying the number of gallons of (leaded or unleaded) paint produced by the surface coverage per gallon and dividing that figure by the average paintable surface area of a dwelling unit, which was estimated to be 4200 square feet. A more realistic estimate can be made by assuming that the interior of a home is repainted every 3 years. Under those circumstances an average area of 1400 square feet would then be painted per year. Calculations using the 1400 square feet figure indicate as shown in table 1 that the number of dwelling units probably painted with leaded paints varied from about 11-1/2 million in 1939 to 0.4 million in 1967.

According to the 1960 housing census, more than 30 million of the occupied housing units in use in 1960 were built prior to 1940. Of these 30 million occupied housing units, 5-1/2 million were classified as deteriorating and almost 2 million ad dilapidated. There are, then, 7 million dwelling units in the United States today that are in advanced stages of disrepair, that probably contain lead paint and are an immediate hazard to the children living in them.

Apartment houses built in metropolitan areas between 1900 and 1930 were essentially old buildings by the 1950's, with outdated plumbing, electrical supply and heating systems. Families moving in and out with increasing frequency showed little concern for the care of their rented rooms. Absentee owners either shared that lack of concern or could not

Table 1

ESTIMATED LEAD PAINT PRODUCTION AND USAGE IN RESIDENTIAL INTERIORS

		1939	1947	1954	1958	1963	1967
Total Paint Production	MG	(183)	(385)	411	447	535	551
All Interior House Paints	MG	(72)	(129)	130	139	167	162
All Lead Paints	MG	(58)	(78)	(34)	(23)	(16)	(11)
Interior Lead Paints[1]	MG	(33)	(46)	(19)	(13)	(9.5)	(6.8)
Coverage, All Interior House Paints[2]	BSF	(32)	(58)	59	63	75	73
Coverage, Interior Lead Paints[2]	BSF	(14.9)	(20.7)	(8.6)	(5.9)	(4.3)	(3.1)
Total Housing Stock (Occupied)[3]	MDU	(34.5)	(40.5)	(47.0)	(51.0)	(56.0)	(59.5)
Est. No. D.U. Interiors Painted	MDU						
All Interior Paints[4]	(4200 SF/DU)	(7.6)	(13.8)	14.0	15.0	17.9	17.4
All Interior Paints[5]	(1400 SF/DU)	(22.8)	(41.4)	42.1	45.0	53.6	52.1
Interior Lead Paints[4]	(4200 SF/DU)	(3.6)	(4.9)	(2.0)	(1.4)	(1.0)	(0.7)
Interior Lead Paints[5]	(1400 SF/DU)	(10.6)	(14.8)	(6.1)	(4.2)	(3.1)	(2.2)

[1] These values were obtained by multiplying the figures for All Interior House Paints by the fraction of House Paint containing lead.
[2] Based on 450 square feet/gallon coverage.
[3] Extrapolated from Bureau of Census Housing Reports.
[4] Wall and ceiling surface area for average dwelling unit.
[5] One-third of the total paintable surface of dwelling unit.

MG stands for million gallons.
BSF stands for billion square feet.
MDU stands for million dwelling units.
Figures in parentheses are estimated values.

afford to match the rate of repair to the rate of collapse or destruction. Today those buildings number in the tens of thousands in the ghettos of large cities. The interiors of the rooms in such housing are scenes of cracked and falling plaster and peeling paint. In many of those houses there are electrical, plumbing and structural code violations in addition to the lead paint problems. Extremely bad conditions are likely to be found in areas that are constantly exposed to moisture such as bathrooms and kitchens. Public areas such as halls and stairwells are often more dilapidated than apartment interiors when children are allowed to play there unsupervised.

One solution to the lead paint poisoning problem is very simple; eliminate the sources of lead that children can come in contact with. This could be done very easily within the framework of existing technology, but with the cost of deleading a residence ranging from a few hundred dollars up the thousands of dollars, and with millions of dwelling units involved, the costs would be enormous.

Guidelines are needed to acquaint municipal planners and other decision makers with the factors that should be considered in establishing programs to delead housing. Such guidelines should be of particular value to those cities that have had no previous experience in dealing with the problem. Questionnaires and worksheets are needed to assist authorities to determine the source of the hazard, to determine the extent of the hazard, and to consider the factors that should be evaluated in the process of choosing particular methods for deleading.

One performance requirement that must be considered above all others, in making a decision about deleading, is that the method used should reduce or eliminate the exposure of susceptible children to lead poisoning. There are two basic technological procedures that can be used to achieve the goal of hazard elimination. One is removal of all hazardous material, and the other is covering it up to make it inaccessible. Only the complete application of one of the methods will make a residence completely lead-free. If deleading is less than complete, the potential recurrence of the problem due to continued accessibility of the residual leaded material must be considered.

Four conditions of lead paint availability have been defined. Condition 1 is the immediate hazard of easily available leaded material that may be lying around or blistering and peeling on reachable surfaces. The easy access to any paint, plaster or sealant containing lead defines this condition. Condition 2 is the immediate to potential hazard of tightly adhered leaded material which is on chewable surfaces such as window sills, moldings and door edges or which can otherwise be made available by impact, scratching or gouging within the limits of a child's reach. Condition 3 is the potential hazard of tightly adhering leaded material which will apparently become loosened and available to the child because of environmental conditions such as water leaks, condensation or some physical deterioration of the building. Condition 4 is the unlikely hazard of tightly adhering leaded material apparently secure on its surface with small possibility of it ever becoming available to a child.

In addition to the principal attribute of eliminating the accessibility of the hazard, there are secondary factors to be considered in choosing deleading procedures which include:

Installation health and safety as it pertains to workmen.

Ancillary work including plumbing, electrical and heating system changes that may be required.

Waste disposal which becomes a major economic and health problem when plaster walls are completely removed.

Community and user involvement which relates to the use of local unskilled labor to carry out the deleading procedures and the acceptability of the work by the people in the community.

The degree of finish which also pertains to acceptability, durability and service life.

The cost of labor, materials, equipment and supportive costs inculding occupant relocation.

The time required to carry out deleading methods which also affects cost and occupant relocation.

In-use performance which will affect long-range occupant health and safety through the durability and stability of the procedure finally decided upon.

Hazard accessibility is related to both the degree of hazard elimination and the deleading method used. For example: if only loose leaded material and leaded material on chewable surfaces are removed, then the remaining leaded material can become accessible when further delamination occurs within a child's reach or when that tight material becomes loosened due to natural causes such as moisture. If a covering that can be torn away is used then the hazardous material beneath it is once again made accessible.

Certain prerequisite conditions must be satisfied before some hazard elimination techniques can be used. For example: if a flexible wall covering were to be installed with an adhesive, then all the loose and peeling paint and plaster would have to be removed. The remaining surfaces would have to be free of moisture, oil and dirt. If rigid boards were to be applied, there would be certain support requirements that would have to be met, such as the planarity of supports and support spacings for the new wall. Many of the available hazard removal techniques have health and safety problems associated with them. For example: removing leaded paints by sanding or sand blasting produces a poisonous leaded dust. Softening leaded paint with an open flame so that it can be scraped off more easily creates a fire hazard in addition to exposing workers to lead fumes. Certain procedures including putting up wall board may require additional ancillary work to be done such as the relocation of plumbing, electrical and heating fixtures.

In some cities, apartments and houses are being deleaded and rehabilitated by ripping out old plaster walls and replacing them with drywall or other rigid paneling systems. This process creates serious waste disposal problems. If the paint and plaster are removed from the walls and ceiling of a ten foot by ten foot room, there is going to be almost 1,000 pounds of trash to dispose of. If there are as many as 20 layers of paint on the wall there may be 40 to 50 pounds of paint containing as much as 10 pounds of lead in that waste. If that is multiplied by 6 rooms one has 6,000 pounds of trash with 300 pounds of paint and 60 pounds of lead. Multiply that again by 1,000 apartments and a massive problem is created. If leaded waste is buried, lead may dissolve in ground water and spread to adjoining areas. If it is burned in city incinerators, lead will be dispersed into air that is already heavily leaded. If it is left in the streets or alleys it is an even greater hazard to the children from whose dwellings it was originally taken.

Some detoxification procedures leave the dwelling in a rough unfinished state unless further finish work is done. Other methods provide an attractive surface in the course of carrying out the method. Gypsum board for example should be painted to improve its appearance, to make it easy to clean and to improve its moisture resistance. Minimum property levels should be established to try to ensure adequate in-use performance of hazard elimination systems. With reference to occupant health and safety, factors such as fire resistance, toxicity, mold growth, and dirt collection resistance should be considered. Under durability and stability there are scratch, impact, abrasion, and moisture resistance. The systems and materials used for hazard elimination should be acceptable to the housing occupants. Factors such as washability and maintainability of the surface, acoustic properties; color; and reflectance should be considered for this reason.

5. Conclusion

Very limited resources are now available to the cities for lead paint poisoning control. Virtually all of their efforts are devoted to finding and treating children who have dangerously high levels of lead in their bodies. Widespread screening of housing and removal of the hazard from all dwellings containing accessible leaded materials is not economically feasible today but in view of the nature of the problem and the disease, that approach offers the only realistic solution for completely eliminating the problem.

Several temporary methods can be used to prevent accessibility to lead paint. Loose or peeling paint can be scraped off walls, woodwork and ceilings. Woodwork that a child may chew on can be covered with contact paper or tape; holes and damaged plaster can be covered with paper, cloth or cardboard using tape or paste to hold the patches. Lead paint can be removed by sanding or scraping. The paint can be softened with chemical solvents or heat to facilitate scraping. Lead paint can be covered up with more permanent rigid materials such as gypsum board, hardboard or plywood. Membrane type materials such as fabrics, liquid plastics, wall paper or veneer plaster can be used to cover up lead paint (only if the walls are in good condition).

The primary criterion for the selection of a hazard removal method is how well it performs in eliminating the hazard from the child's environment. Next to that consideration, cost is probably of greatest importance in the final selection of a method. Cost data can be obtained in two ways: first by a survey of current practice in cities with lead poisoning control programs and secondly by direct analysis of the labor, material, equipment and other costs associated with the various hazard elimination methods. The lead paint elimination costs and rehabilitation costs currently available from New York City and Chicago are expressed in terms of total cost per dwelling unit or total cost per square foot of treated surface. (New York and Chicago estimate deleading costs at $1 per square foot.) Costs presented in that format are useful as "rule of thumb" budget estimates but they cannot be used as comprehensive source data for the evaluation of the cost effectiveness of each deleading method. Even with data presented on a square footage basis it is still difficult to predict what an average dwelling unit cost would be. The most obvious problems in cost analyses are the variation in dwelling unit size and the amount of supportive work to be done. Another important element, is the lack of knowledge of what constitutes adequate deleading. Research is continuing to obtain a better definition of that point.

The hazard of lead paint is defined by two factors:

1) the presence of toxic quantities of lead based materials on walls, ceilings or woodwork and

2) the deteriorated condition of those surfaces that makes the leaded material accessible to a child who has pica (the desire to eat unnatural foods).

It is obvious that priorities must be set for the deleading of hazardous dwellings. The cities that currently have lead poisoning control programs justifiably require as a first priority the deleading of the homes of children who have lead poisoning. The second priority should be assigned to the housing that contains lead and is in advanced stages of deterioration. A low priority should be given to housing that contains lead but is well maintained and does not present an immediate hazard.

Consideration must also be given to new or other housing not yet containing the lead paint hazard. Limiting lead in currently manufactured paints and coatings will not materially affect the incidence of poisoning of children who eat dried paint in deteriorated housing. But it will accomplish the removal of the hazard of lead in paints for future generations. Since 1950 several cities have passed ordinances which provide some control over the use or sale of leaded paints. Some cities ban the sale or use of leaded paints for interior surfaces of dwelling units. Others only require that paints containing greater than a certain lead level bear an adequate label that warns against its use on surfaces accessible to children. Under Title IV of PL 91-695, the Secretary of HEW is directed "to take such steps and impose such conditions as may be necessary or appropriate to prohibit the use of lead based paint in residential structures constructed or rehabilitated by the Federal government, or with Federal assistance in any form."

The more we learn about lead paint poisoning the more we recognize that lead pollution is a major environmental problem that should be of great concern to all of us. The sources of the lead hazard are air, water, food and industrial wastes as well as lead paint. The child who is a potential victim because he lives in bad housing needs more than pica to become a victim in fact. Social, economic, biological and geographical factors also contribute to lead poisoning. The destructive consequences of this disease are not only medical but obviously social and economic as well. The problem is cyclic--the consequences of lead poisoning establish the base for the problem to confron the next generation of children living in the same, if not worsening, environment. A concerted national effort is required to eradicate this disease--the cooperation of all levels of government is needed no less than the cooperation of all of the technical competences that relate to the problem. The medical people must find better ways to detect and treat lead poisoning. The scientists and engineers, both hard and soft, must show us how to solve the human and environmental problems. And finally, but most importantly, local, state and Federal governments must find the way to implement those solutions.

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The National Bureau of Standards is providing technical support required by the Department of Housing and Urban Development to carry out its research responsibilities under PL 91-695, The Lead Based Paint Poisoning Prevention Act. The program at NBS has involved three major areas of research: (1) an estimation of the numbers of children at risk and with excessive body burdens of lead and the geographical distribution of those children; (2) the capabilities and characteristics of analytical methods for the detection of lead in paint and other building materials and (3) the identification and evaluation of materials, techniques and systems for removing or eliminating the lead paint hazard from housing. This paper is a brief presentation of the activities and conclusions of NBS in the areas listed above.

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