A UNITED STATES
DEPARTMENT OF
COMMERCE
PUBLICATION

NBS TECHNICAL NOTE 746

Estimates of the Nature and Extent of Lead Paint Poisoning in the United States

U.S.
EPARTMENT
OF
COMMERCE
National

NATIONAL BUREAU OF STANDARDS

The National Bureau of Standards[1] was established by an act of Congress March 3, 1901. The Bureau's overall goal is to strengthen and advance the Nation's science and technology and facilitate their effective application for public benefit. To this end, the Bureau conducts research and provides: (1) a basis for the Nation's physical measurement system, (2) scientific and technological services for industry and government, (3) a technical basis for equity in trade, and (4) technical services to promote public safety. The Bureau consists of the Institute for Basic Standards, the Institute for Materials Research, the Institute for Applied Technology, the Center for Computer Sciences and Technology, and the Office for Information Programs.

THE INSTITUTE FOR BASIC STANDARDS provides the central basis within the United States of a complete and consistent system of physical measurement; coordinates that system with measurement systems of other nations; and furnishes essential services leading to accurate and uniform physical measurements throughout the Nation's scientific community, industry, and commerce. The Institute consists of a Center for Radiation Research, an Office of Measurement Services and the following divisions:

> Applied Mathematics—Electricity—Heat—Mechanics—Optical Physics—Linac Radiation[2]—Nuclear Radiation[2]—Applied Radiation[2]—Quantum Electronics[3]—Electromagnetics[3]—Time and Frequency[3]—Laboratory Astrophysics[3]—Cryogenics[3].

THE INSTITUTE FOR MATERIALS RESEARCH conducts materials research leading to improved methods of measurement, standards, and data on the properties of well-characterized materials needed by industry, commerce, educational institutions, and Government; provides advisory and research services to other Government agencies; and develops, produces, and distributes standard reference materials. The Institute consists of the Office of Standard Reference Materials and the following divisions:

> Analytical Chemistry—Polymers—Metallurgy—Inorganic Materials—Reactor Radiation—Physical Chemistry.

THE INSTITUTE FOR APPLIED TECHNOLOGY provides technical services to promote the use of available technology and to facilitate technological innovation in industry and Government; cooperates with public and private organizations leading to the development of technological standards (including mandatory safety standards), codes and methods of test; and provides technical advice and services to Government agencies upon request. The Institute also monitors NBS engineering standards activities and provides liaison between NBS and national and international engineering standards bodies. The Institute consists of a Center for Building Technology and the following divisions and offices:

> Engineering Standards Services—Weights and Measures—Invention and Innovation—Product Evaluation Technology—Electronic Technology—Technical Analysis—Measurement Engineering—Fire Technology—Housing Technology[4]—Federal Building Technology[4]—Building Standards and Codes Services[4]—Building Environment[4]—Structures, Materials and Life Safety[4]—Technical Evaluation and Application[4].

THE CENTER FOR COMPUTER SCIENCES AND TECHNOLOGY conducts research and provides technical services designed to aid Government agencies in improving cost effectiveness in the conduct of their programs through the selection, acquisition, and effective utilization of automatic data processing equipment; and serves as the principal focus within the executive branch for the development of Federal standards for automatic data processing equipment, techniques, and computer languages. The Center consists of the following offices and divisions:

> Information Processing Standards—Computer Information—Computer Services—Systems Development—Information Processing Technology.

THE OFFICE FOR INFORMATION PROGRAMS promotes optimum dissemination and accessibility of scientific information generated within NBS and other agencies of the Federal Government; promotes the development of the National Standard Reference Data System and a system of information analysis centers dealing with the broader aspects of the National Measurement System; provides appropriate services to ensure that the NBS staff has optimum accessibility to the scientific information of the world, and directs the public information activities of the Bureau. The Office consists of the following organizational units:

> Office of Standard Reference Data—Office of Technical Information and Publications—Library—Office of International Relations.

---

[1] Headquarters and Laboratories at Gaithersburg, Maryland, unless otherwise noted; mailing address Washington, D.C. 20234.

[2] Part of the Center for Radiation Research.

[3] Located at Boulder, Colorado 80302.

[4] Part of the Center for Building Technology.

not acc.

Estimates of the Nature and Extent of Lead Paint Poisoning in the United States

Judith F. Gilsinn

Applied Mathematics Division
Institute for Basic Standards
National Bureau of Standards
Washington, D.C. 20234

U.S.

t. Technical note no. 746

Report to
Lead Paint Poisoning Project
Center for Building Technology
Institute for Applied Technology, NBS

Sponsored by
Department of Housing and Urban Development
Washington, D.C. 20410

U.S. DEPARTMENT OF COMMERCE, Peter G. Peterson, *Secretary*
NATIONAL BUREAU OF STANDARDS, Lawrence M. Kushner, *Acting Director*,

Issued December 1972

National Bureau of Standards Technical Note 746
Nat. Bur. Stand. (U.S.), Tech. Note 746, 163 pages (Dec. 1972)
CODEN: NBTNAE

For sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402
(Order by SD Catalog No. C13.46:746). Price $2.00

Preface

The research described in this report was sponsored by the Department of Housing and Urban Development and was conducted under the overall direction of the Lead Paint Poisoning Project Manager, Harvey Berger of the Center for Building Technology (CBT) at the National Bureau of Standards (NBS). The staff members who participated in the effort described herein include members of both NBS' Technical Analysis Division (TAD) and its Applied Mathematics Division (AMD). Principal technical contributions were made by Judith Gilsinn and Lambert Joel of the AMD and Dr. Michael Thomas of the TAD and the University of Florida. Supporting staff from TAD included Barbara Reisman, Barry Nocks, Stephen Karp, Peter Corcoran, Louis Clark, Elizabeth Leyendecker, William O'Neal, and Dr. Ernst Nilsson.

Many others furnished information and guidance contributing to the success of this effort. Special thanks are due Gary Tollaksen and Barbara Ruby of the Aurora Service Center of the Kane County (Illinois) Council on Economic Opportunity for their cooperation and help in providing, coding, and interpreting data from Aurora's lead poisoning screening program.

We are also indebted to Elaine Whitmire, Coordinator of the Lead Paint Poisoning Program, New Haven, Connecticut; Dr. J. Julian Chisolm, Johns Hopkins University School of Medicine and the Baltimore City Hospitals; Raymond Tyler, Chief of the Accident Control Division, Philadelphia Department of Public Health; Dr. Herbert Slutsky, Lead Program Coordinator, Chicago Board of Health; Daniel Still, Lead Poisoning Control Bureau, New York City; and members of HEW's Bureau of Community and Environmental

Management. Their discussions with us greatly expanded the staff's knowledge concerning current expert assessments of the magnitude and extent of lead poisoning and of the efforts being made to combat it.

We wish to thank Dr. Irwin Billick of the Department of Housing and Urban Development for his help in identifying sources of lead poisoning information and his help in acquiring that information.

Special thanks are extended to Dr. Alan Goldman, Chief of the Operations Research Section of the Bureau's AMD, for his many technical suggestions and for his critical reading of this and other project reports.

We wish to thank Dr. David Waksman and Elizabeth Clark of the Bureau's CBT for their patient and skillful explanations of a number of technical points about paint production and building technology.

We also wish to thank Ruth Joel and Karen Rhoades for their patience in typing the many drafts of this report.

TABLE OF CONTENTS

PAGE

List of Tables

LIST OF FIGURES

Estimates of the Nature and Extent of Lead Paint Poisoning in the United States

Judith Gilsinn

This report evaluates the nationwide magnitude and extent of pediatric lead poisoning resulting from the ingestion of lead-based paint. Estimates are given of the number of children who have elevated blood lead levels (40 μg or more of lead per 100 ml of whole blood) in each of 241 Standard Metropolitan Statistical Areas throughout the country. The mathematical models used to obtain these estimates are documented together with the assumptions and data upon which those models are based. Partial validation of both models and assumptions is also reported.

Key words: Childhood diseases; estimation; health problems; lead; lead paint; lead paint poisoning; lead poisoning; mathematical modeling; models; urban health problems.

1. INTRODUCTION

Lead poisoning resulting from the ingestion of lead based paint is a serious illness which has recently been recognized as a major pediatric problem. Several cities have initiated programs to locate and treat lead poisoned children, and in January 1971 the United States Congress enacted PL 91-695, the "Lead Based Paint Poisoning Prevention Act", to provide Federal assistance to help eliminate the disease. Title III of this act calls for research to determine the nature and extent of the lead paint poisoning problem. This research is to be coupled with analyses of lead detection procedures and removal methods, to provide a set of recommendations that can form the basis for future action against lead poisoning.

1.1. Description of Lead Poisoning

Lead poisoning today is a disease primarily affecting children 1 to 6 years old[1], although some cases of adult poisoning are still reported. These latter fall mainly into two groups: industrial or work related, such as poisoning of painters who have worked for many years with lead paints, and domestic, e.g., individuals poisoned by eating or drinking an acidic substance such as orange juice or applesauce which had been stored in a ceramic container with an improperly fired glaze from which lead had been leached by the acid.

It has been estimated that about 90 percent of the pediatric lead poisoning cases result from a child eating peeling, cracking, or flaking paint or painted plaster inside his home.[2] (Plaster itself does not contain lead, but its upper layers absorb lead-containing oil from the paint.) Other sources of lead which have led to poisoning include putty and caulking, lead-painted gutter pipes, fences, imported toys, and pencils, toothpaste tubes made of a lead alloy, lead shot in beanbags, lead fishing sinkers, and lead pottery glazes. Air pollution has also been cited as a cause of lead poisoning.[3] Recently (early 1972), several children living near a smelter in El Paso, Texas, were found to show signs of undue lead absorption. Soil samples taken near the smelter showed very high lead levels, indicating that lead in the air had settled and accumulated in the soil. The major source of lead pollutants in the air, however, is non-industrial: leaded gasoline fumes. The relative importance of lead in gasoline and lead in paint as causative factors of lead poisoning is currently being debated, but most experts conducting child screening programs believe that paint eating, if not the only factor, at least is the major factor precipitating the onset of the disease.[4]

The following sections concern the characteristics of, testing for, and treatment of lead poisoning. They contain some medical and chemical terms which are not explained in the text. The interested reader is referred to [7], [11], [12], [18], and [40] for further information.

1.1.1. Symptoms of Lead Poisoning

The initial symptoms of lead poisoning are very non-specific and might be due to many other agents, making it easy for physicians and parents to misdiagnose the disease or to overlook it entirely. These symptoms include nausea, vomiting, abdominal pain, constipation, anemia, irritability, anorexia and listlessness. If untreated, the disease may lead to central nervous system involvement (lead encephalopathy) which can result in blindness, paralysis, mental retardation, and finally death. Less severe cases of lead absorption may leave the victim with learning problems, partial loss of sensory perception, and behavioral and other emotional difficulties. Some experts have also noted cardiovascular and renal damage.[5]

1.1.2. Lead in the Body

The effects of lead in the human body are incompletely known, but it fulfills no apparent necessary role in the body chemistry. It has been estimated that approximately 5 to 10 percent of ingested lead is retained in the bones and soft tissues,[6] the rest being excreted, while about 40 percent of respired lead is retained.[7] Using these figures, the daily permissible intake (DPI) of lead has been set at 300 μg/day.[8] About half of this would be absorbed from normal contamination levels in food, water, and the air. The other 150 μg allow for abnormal levels in food, water, and air and for other possible sources such as paint. Since a single paint chip the size of a thumbnail may contain several times the DPI, a child eating any lead paint at all runs a great risk of being poisoned.

A phenomenon generally noted by those working with lead poisoning is that the number of cases rises in the summer. Several explanations have been offered, but none has been completely satisfactory. A possible physiological explanation lies in the (incompletely understood) relationship between lead absorption and the amount of ultraviolet light to which the child is exposed.[9] Lead follows the same metabolic path as calcium, which has a higher absorption rate in the presence of vitamin D, whose production in turn is affected by ultraviolet light. In addition, some experts have hypothesized that ultraviolet light is a stimulus for release into the blood of lead stored in the bones.

On the other hand, in general the number of reported cases rises as more effort is spent in looking for them. It is in the summer that many cities are able to mount community outreach programs using volunteer workers to go into neighborhoods to encourage parents to bring their children to clinics for testing.

Yet another possible explanation for the higher summer rates is that during the warmer months children spend more time out-of-doors, with greater exposure to additional sources of lead in dirt, automobile exhaust fumes, and peeling leaded exterior paint.

1.1.3. Pica

Another condition closely associated with lead poisoning is pica, an unreasonable craving for non-food substances. All children go through an oral exploratory stage, lasting up to about 3 years of age, during which they mouth objects within their reach. However some children continue the stage beyond this age, or are unusually persistent in "attacking" certain objects. Typically, a child might strike at a wall with a toy in order to break off pieces of plaster to eat, or might rearrange furniture to enable him to climb up to get medicine placed in a cabinet high above his reach, in spite of repeated admonitions by parents. It is virtually impossible to keep such a child from eating chips of lead paint if they are accessible to him; no mother can constantly supervise an active two year old child determined to chew on paint.

Pica was originally regarded as linked to nutritional deficiency, but studies conducted at Children's Hospital in Washington, D.C. have found no relationship between the two.[10] Pica has been found, however, to be associated with situations of emotional stress in the child's family. Another factor is the mother's tolerance of pica. If she had pica as a child or comes from an area where such practices as clay or starch eating are common, she may consider the child's pica as normal, and thus do nothing to correct it. This attitude may also degrade the usefulness of certain questions frequently appearing on questionnaires designed to elicit information on pica: some mothers may in all honesty answer that their child does not eat "unusual substances"--don't all children eat matches, dirt, or paint?

1.1.4. Method of Testing for Lead Poisoning

Because the initial symptoms of lead poisoning are so inconclusive, while permanent damage has already been done by the time more identifiable symptoms appear, it is necessary to have a method of measuring the total body burden of lead and of identifying children in danger of being poisoned. Although several tests are available, the Public Health Service recommends the blood lead determination as "the most consistent indicator of acute exposure."[11] The "normal" median blood lead level of children is believed to be 16 to 27 μg lead per 100 ml of whole blood (abbreviated μg/100 ml), and levels in the range of 15 to 40 μg/100 ml are considered normal. The Public Health Service recommends that a blood lead concentration of 80 μg/100 ml or more, regardless of other laboratory test results or of the presence or absence of other symptoms, be considered unequivocally definitive evidence of lead poisoning and be treated as a medical emergency requiring hospitalization for chelation therapy.

The Public Health Service also recommends that children whose blood lead level is in the 50-70 μg/100 ml range should be referred for further diagnosis. The presence of symptoms of lead poisoning unexplained by other circumstances, or of positive results on any of the following confirmatory tests, is regarded by the Public Health Service as suggestive of lead poisoning:

1. Urinary excretion in 24 hours of more than 1 μg of lead per mg of Ca-EDTA administered intra-muscularly at a dose of 50 mg per kg of body weight;
2. Serum delta-aminolevulinic (ALA) level of greater than 20 μg per 100 ml of whole blood established using the Haeger-Aronson method;
3. Urinary output of coproporphyrin greater than 150 μg per 24 hours;
4. Urinary output of delta-aminolevulinic acid greater than 5 mg per 24 hours, (this will be called the ALA urine test in later sections of this paper);
5. The presence of basophilic stippling of red blood cells, "lead lines" in long bone x-rays, or a strongly positive urine spot test for coproporphyrin.[12]

The Public Health Service recommends that children whose blood lead level falls in the 40 to 49 μg/100 ml range should be recalled every 6 to 8 weeks for retest and evaluation with determination of blood lead level, as long as they remain in a hazardous environment.

Several analytical methods are available for measuring blood lead. They include:

1. the spectrophotometric dithizone technique
2. atomic absorption spectrophotometry (AA), and
3. anodic stripping voltammetry (ASV).

The first of these is a wet chemistry technique requiring a macro-blood sample (about 5 ml) obtained by venipuncture. The other two methods can be used to analyze macro samples as well as small samples (20-100 μl) obtained by a finger prick. A method requiring only a finger prick is desirable on grounds of both public acceptance, since venipuncture is painful, and cost, since venipuncture requires more highly trained personnel. However, recent experience has shown that the risk of contamination of the small finger prick samples is very great, since the amount of lead in such a small sample is minute even at critically high levels, and lead may easily be introduced from lead-polluted dirt and air.

1.1.5. Screening

Several cities have set up programs for screening children for lead poisoning, testing all children in an area or all who come to a particular clinic or hospital, to identify those with dangerously elevated blood lead levels. Most programs carefully choose the population to be tested so as to maximize the fraction of those tested expected to be identified as lead poisoning cases. Some programs restrict their testing to areas with substandard old housing in a deteriorating condition which offers a peeling lead paint hazard. Others test all children coming to health clinics or to hospitals, hoping to catch those with symptoms of the disease. Thus most programs, having limited funds, have made a (sometimes tacit) decision as to which children are at greatest risk, and have concentrated efforts on such children. From a health viewpoint the most desirable child screening program is one that would test all children, but a program of such magnitude is not possible under current or projected funding levels. Therefore, better estimates of the characteristics of these children at greatest risk are needed to permit a more accurate and reliable focusing of screening efforts.

An alternative screening procedure is possible--test all homes in an area for lead content, and once a lead hazard environment is identified, test the children living there. This procedure could be very useful if the program includes removal of the lead hazard from every home where one was found, as well as treatment of children with dangerously high blood lead levels. However, since most programs have funds only to test and treat children, the "screen house first" approach is not being used at present.

1.1.6. Treatment of Lead Poisoning

The primary goal of lead poisoning treatment is the removal of the excess lead from the child's body. This is accomplished through chelation therapy,[13] which must be performed under carefully controlled supervision, since the initial response may be an increase in blood lead level as lead is released from the bones. Chelation may also draw calcium from the bones if too high a dosage is prescribed.

1.1.7. Removing the Lead Hazard

In addition to reducing the body burden of lead, which lessens the immediate danger to the child, it is necessary to remove the source of lead poisoning from his environment. If the child is returned to an unchanged environment he runs the same risk as before; the lead is still there to be ingested. More intense supervision can alleviate the danger somewhat, but the only way to insure protection of this child--and others living in the same housing unit now and in the future--is to remove the lead hazard. The Public Health Service recommends that no child be returned to his home until the source of lead exposure has been identified and either eliminated or made unavailable. It suggests that convalescent homes, halfway houses, public housing, or hazard-free relatives' homes be employed during the interim.[14]

Although there are many areas with small programs to identify and treat children with lead poisoning, few areas have programs to remove the lead paint hazard from dwelling units. There are several reasons for this, the principal one being lack of money. Deleading a dwelling unit can be very expensive. Costs can range from a low of a few hundred dollars to scrape off loose and peeling paint, to a high of five or six thousand dollars for a major rehabilitation effort. Since units offering an immediate lead hazard in the form of peeling and flaking lead paint are often rental units owned by landlords making marginal profits or units owned by lower income residents, the owners are unable and/or unwilling to make the repairs necessary to eliminate the hazard. Limited city funds are inadequate to delead more than a token number of units. Some federal funds are available, but eligibility for such grants is limited. In addition, there is a several-month time lag between application for federal funds and the actual granting of such funds. During this time period the child remains exposed to the danger of lead poisoning.

Many cities have laws against the sale of lead paint and its use on interior surfaces accessible to children. Such laws often assign enforcement powers to Health or Housing Departments in the city or state. Table 1 summarizes the characteristics of such regulations for several areas. The table lists which authority (health or housing) has jurisdiction, whether there is a statute requiring cautionary labeling of lead paint for sale, whether there is a law banning the use of lead paint on interior surfaces, whether the authority includes enforcement powers, and finally if the existence of peeling paint is a violation of the code.

Table 1

Lead Paint Regulations

Area	Health or Housing	Label Paint for Sale	Not On Interior Surfaces	Can Force Removal	No Peeling Paint	Source
Baltimore	Housing	yes	yes	yes	yes	Baltimore Lead Paint Labeling Ordinance #1504, 6/9/58, Housing Code, Ordinance #902, 1951
Boston	Health		yes	yes		
Chicago	Housing	yes	yes	yes	yes	Municipal Code of Chicago, Section 78-17.2
Cincinnati	Health	yes	yes	yes		Cincinnati Lead Ordinance, 1960
Connecticut	Health, Housing	yes	yes ("accessible surfaces")	yes	yes	Public Act 194 - An Act to Enforce the Elimination of Lead Based Paint in Housing Accomodations, 1971
Jersey City	Health	yes	yes	yes		City Ordinance #G-36 - An Ordinance Regulating the Sale of Lead Paint in the City of Jersey City, 1962
Massachusetts	Health	yes	yes + exterior	yes		Chapter 1081, An Act Providing for a Comprehensive Program of Lead Poisoning Prevention and Control-1971
Newark	Health	yes	yes	yes		Ordinance Numbers 8B102170, 8C102170, 8D102170, 8E102170, and 8F102170 of the City of Newark, N.J., Nov. 1970.
New Haven	Health, Housing	yes	yes + (accessible exterior)	yes		Amendment of Housing Code Relative to Lead Paint on Dwelling Units 1968 - Lead Paint Ordinance - 1968
New Orleans	Health	yes	yes + (accessible exterior)	yes		Ordinance 828 amended 1971
New York State	Health	yes	yes + (accessible exterior)	yes		Official Compilations of Codes, Rules and Regulations of the State of New York (Health) 1970. An Act to Amend the Public Health Law in Relation to the Prevention and Control of Lead Poisoning
New York City	Health	yes	yes	yes		New York Administrative Code - Lead Paint Regulations 1970
Norfolk	Housing				yes	
Rhode Island	Health			yes		
Philadelphia	Health	yes	yes	yes		Regulations Relating to Labeling, Application, and Removal of Lead Paint 1966
St. Louis	Housing	yes	yes + (disintegrating)	yes	yes	Ordinance 55638-Lead Poisoning Ordinance 1970
Washington, D.C.	Health, Housing		yes	yes	yes	Health Regulations, Part 9 Use of Lead Paint, 1970, Housing Regulations Section 2605, 1970
Wilmington	Health	yes	yes	yes		Ordinance Regulating and Governing the Hygiene of Housing and Enacting a Housing Code in Wilmington, Del., section 7A, Lead Paint, 1963

In some areas the primary responsibility for lead paint poisoning prevention lies with the health department. This has some advantages, in that health problems in general receive more immediate attention than housing problems. Also, health officials are often the ones making first contact with a poisoned child, so that leaving deleading enforcement in their hands requires fewer interdepartmental delays. The disadvantage, when primary enforcement of deleading is based on establishing the existence of a health code violation, is that court proceedings often require demonstration that the presence of lead paint in the unit is the "cause" of lead poisoning in the child. For instance, in a recent Maryland decision[15] the court found in favor of a landlord, saying the mother may have been contributorially negligent in not having supervised the child carefully enough.

In other cities, primary deleading enforcement responsibility lies in the hands of housing officials. This simplifies the problem of proving landlord negligence, since most laws require only proof that an interior surface contains paint with a lead content in excess of a given level (usually 1 percent). Cities lacking specific ordinances against lead paint often use regulations against peeling paint (regardless of lead content) to enforce removal. This is less desirable, since lead paint which is tightly adhered today may become loosened in the future.

Although enforcement powers have been given to officials in many cities, they are reluctant to use them for several reasons. Many buildings in a condition requiring deleading are marginal income investments (i.e., provide little if any profits) for the landlords. The expense of deleading would force them into abandoning their property. Cities already faced with a shortage of low income housing do not wish to trigger further abandonments. In addition, deleading enforcement requires court action, an expensive and time consuming procedure for already overtaxed city departments. Thus most cities which issue deleading orders report high levels of non-compliance with those orders.

The lack of active deleading programs contributes greatly to the high number of repeaters, children who were treated once yet have dangerously elevated blood lead levels again a few months later. Of course, the danger that such children will suffer permanent damage is very great.

1.2. Need for a Model

As described above, pediatric lead poisoning is a solvable problem. It has a known cause (the ingestion of lead based paint), there is a known test for the early identification of children with the disease, the method of treating children with the disease is known, and the lead hazard in homes can be identified and removed. However the cost to do all this is high and may be prohibitive. The magnitude and extent of lead poisoning in the United States must therefore be estimated, to ascertain what level of commitment of resources is most appropriate to alleviate the problem and to determine where those resources can most effectively be applied. If humanitarian considerations were set aside, one must know how many children are afflicted to be able to estimate the economic cost to society of doing nothing about the disease, both the direct costs of custodial care required for brain damaged children and the indirect costs of the loss of potentially productive members of society. One must know where the disease occurs to verify that the problem is of nationwide, rather than regional, extent and to ascertain in which geographical areas the urgency for intensive screening and deleading efforts is greatest.

Current lead poisoning screening programs are for the most part funded by the cities or states. Only two cities, New York and Chicago, have programs funded at a level permitting mass child screening. These two programs also have (limited) funds to be used for deleading homes. Many areas have no screening programs, and authorities in some areas are still unaware of the problem or believe it does not exist in their locale, although the environment is similar to that in other areas where the disease has been found. Some cities and states do not require reporting of lead poisoning cases to health authorities, while others report several hundred cases a year. At present, the number of cases found appears to depend more on the effort spent looking for lead poisoning than on the size of the city. Because the symptoms are similar to those of many other ailments, many cases may be misdiagnosed unless local physicians are aware of lead poisoning and test for it. This diversity of local programs, attitudes, and sensitivity to the problem increases the need for a nationwide estimate based on consistent evaluations throughout the country.

The mathematical model described later in this report will relate the magnitude of lead poisoning in an area to characteristics of the people and housing in that area. The underlying assumption is, of course, that one can characterize those areas now reporting lead poisoning well enough to predict which other areas are similar and thus (on the average) should have the same levels of poisoning. The primary purpose of the current model is to estimate the nationwide magnitude and extent of lead poisoning. This will be done by estimating the number of children with elevated blood lead levels (EBL: 40 μg/100 ml or more) separately for 241 metropolitan areas of the country. The present model has not been designed to predict EBL's for separate neighborhoods within a city. However, future work may determine that the same model is applicable at this finer level of geographical detail.

Because of project time and budget constraints, it was necessary to develop the model without mounting a supporting data collection effort. The data base for the model was therefore limited to currently available data, more specifically to those available in a form requiring little further processing. It follows that the results of the present model can only be regarded as "current best estimates", subject to further confirmation and possible modification.[16] Current data do not include information on several aspects of the problem, such as typical EBL rates for rural children, for middle class children living in older well-maintained housing, or for children in the South and West where building practices as well as decorating and painting methods may differ from those in the urban East and Midwest. Thus care must be taken in interpreting model results, particularly in those areas influenced most by these unanswered questions.

1.3. Procedure

The procedure followed in obtaining estimates of the nationwide magnitude and extent of lead poisoning may be divided into four steps:

1. data acquisition,
2. model construction,
3. model validation, and
4. application of the model.

The remainder of this report will present each of these topics in order, describing the background of and work done on each step for the lead poisoning estimation model. However, because these four steps are common to most modeling efforts, we will describe in general terms in this section the objects of and the tasks involved in each.

1.3.1. Data Acquisition

Data acquisition forms a critical facet of all mathematical modeling efforts, particularly when one is modeling an incompletely understood phenomenon, and when no further structured data acquisition can be undertaken. There are several tasks involved in obtaining the necessary data for such an effort. Some of these are conceptual, some "physical", but all involve costs in time and money and therefore all must be included in planning such an effort.

The first task is the determination of relevant data items.[17] This process should, sequentially, choose the dependent variable (that which is to be estimated), identify associated independent variables (the factors on which the estimation will be based), and analyze these independent variables. The choice of dependent variable and associated independent variables may be aided by the use of published material describing the phenomenon being modeled, by an analysis of previous modeling attempts, and by discussions with those having expert knowledge of and experience with the phenomenon. At this early stage one should include any data item which seems at all relevant; excess ones can easily be eliminated later, and repetition of search effort avoided.

The second task is the determination and evaluation of sources of information on these items. This includes the establishment of criteria for comparison of sources, as well as localization of the sources. The evaluation involves an assessment of the real applicability of the desired data, the form in which it is available, and the amount of further processing required for its use. Some evaluation of the quality of data available from a particular source must be made, and if several sources are to be used then the comparability of their data must be examined.

The third and fourth tasks are the acquisition and assimilation of the data. Obtaining copies of existing data may be relatively easy. However, if they must be obtained from several different sources or are in many pieces, the difficulties multiply. "Assimilating" the data refers to several kinds of further processing required to transform raw information into the form required by the modeling process. This may consist of hand-computing of totals, aggregating information into desired categories, coding items into numeric form, punching computer cards, or processing magnetic computer tapes. Combinations of these activities may be necessary, and data from different sources may require different processing entirely.

The final task in the acquisition of data is the preliminary analysis of these data. This is performed to check initial evaluations of the data, to assess the need for more data, to evaluate the relevancy of already available data items and decide if or which others are needed, and to determine if gaps in empirical information exist which must be filled by additional modeling.

1.3.2. Model Construction

Constructing the model involves three stages. The first two of these require that decisions be made about how the model will be used, what kind of model can be obtained, and what form it will take. These decisions are not just technical, but policy decisions set by the "sponsor" as well as analysts. Additional input to these decisions comes from conversations with experts (on the phenomenon being modeled), information gleaned from relevant literature and previous modeling efforts, and the analysis of available data. The first decision concerns the purpose and scope of the model: Is it to be applied primarily by the modeler in order to produce certain desired output, or is it to be applied in situations not subject to the guidance of the modeler? Are the area and level of application known in advance? Are the ranges of the variables known and limited?

The second decision requires the determination of the methodological basis of the model and the form it will take. This will determine whether the bulk of the analysis will be qualitative, involving development of theories, or quantitative, relying mainly on manipulation of numerical data. Some phenomena are amenable to description by a mathematical formula which directly relates some combination of the magnitudes of the causative factors to the magnitude of the effect on the phenomenon involved. Such phenomena are usually physical or chemical in nature, whereas phenomena involving social factors rarely fall into this category and modeling their behavior must rely on statistical techniques. The actual mathematical form of the model is then determined in part by the techniques used and in part by the data analysis, rather than through translation into numerical terms of a known understood process.

The final stage in the construction of models for which no *a priori* mathematical formula is known involves the process of curve-fitting to available data. Known as "calibration", this process requires the determination of those values for the parameters of a particular model form which yield the best matching for the available data set. The resulting models are then compared on the basis of reasonableness of behavior and goodness of fit to the data, and a best overall model is chosen.

1.3.3. Model Validation

Once the model has been constructed it must be validated, i.e., checked out to insure that (1) data anomalies peculiar to one situation are recognized as such and do not become major determinants of the model, and (2) model hypotheses based on the analysis of the phenomenon in one context carry over into others. There are two levels of validation required. The first involves checking the assumptions upon which the model rests, both those determining which factors are important and which can be omitted, as well as those determining model form. The second level of validation is the comparison of the magnitudes of the phenomenon as predicted by the model and as actually occurring, to insure the model is a good estimator. Validity of models lacking an *a priori* mathematical formulation can seldom be completely assured, but confidence in the model estimates can be increased by this process.

1.3.4. Model Application

Once the model has been constructed and validated, it can be applied to yield desired outputs. The outputs can be analyzed in the light of both model formulation processes and the validation exercises, and implications can be drawn from them. It should be noted here that care should always be exercised in examining the outputs of a model formulated primarily through statistical manipulation of data. Conclusions drawn for situations quite different from those represented by the calibration and validation data sets may be misleading or erroneous. Potential pitfalls resulting from levels of aggregation and from the limited numeric ranges of input data must be comprehended before the output can be interpreted intelligently. Thus one should not blindly accept the model output without an understanding of the whole process from which it has emerged.

2. DATA

Data are used in the modeling process in four ways:

1. for model development
2. for model calibration,
3. for model validation, and
4. for model application.

Preliminary analysis of the data can aid in the model formulation by limiting the number of variables required, and can help determine the model's form. Data are used in the model calibration process for determining the best estimates for model parameters. Model validation requires comparing the predicted values of the model's dependent ("output") variable with actual values. The data required for validation must be a different set from that used for model development, but should be from a context as similar as possible to those in which the model will be applied. Finally, it is necessary to have values for the independent model variables in order to apply the model. The first three of the four headings listed above thus require values for both the independent and the dependent model variables, while the last requires values only for the independent variables. Values for a large variety of data items are required during model development, since the model form and content have not been established at that time. Once the model has been formulated, fewer data are required. The data acquisition, assimilation, and analysis process described in Chapter 1 is much the same for all four stages. Since many of the data items required are the same for all stages, one data search should uncover most sources of data for all stages, although hard-to-obtain items may require an ongoing effort to locate further sources.

The data requirements for the lead paint poisoning model may be divided into two categories: medical data on poisoning incidence, to be used for the dependent variable, and demographic data concerning housing and population, to be used for the independent variables. A distinction between these two categories of data is made, because the sources of the two types of data are quite different and the incidence data are not needed for the model application stage.

2.1. Incidence Data

There were several possible dependent variables for the lead poisoning model, i.e., several plausible measures of "the lead paint poisoning problem":

1. the number of lead poisoning cases,
2. the number of children with blood lead levels at or above some cutoff level, and
3. the number of housing units offering a hazard.

This last is useful for estimating the costs of a program for deleading housing, but the primary measure of the lead poisoning problem is the number of children with the disease. The definition of a lead poisoning "case" is, however, quite vague, differing from place to place and doctor to doctor, and sometimes not even being described. In addition, the determination that a child indeed has a case of lead poisoning requires additional diagnostic procedures beyond the preliminary screening. Therefore, use of the number of cases of lead poisoning as the measure of the magnitude of the problem would not allow calculation of the diagnostic costs needed to identify a case (and non-cases).

Thus the measure of the lead poisoning problem estimated by the model described in this report is the (relatively unambiguous) number of children with elevated blood lead levels (EBL). The cutoff level which will be used is 40 μg/100 ml, the level recommended by the Surgeon General as showing undue absorption of lead. Not all children with blood lead levels above this cutoff require treatment, but all require further diagnostic work. This cutoff level thus distinguishes those children who require further scrutiny in addition to the initial measurement of blood lead level, even in the absence of accompanying symptoms. The distribution of blood lead levels above 40 μg/100 ml can be estimated from existing blood lead data, so that fractions of the child population with higher levels can also be obtained.

It is important to remark at this point that all current screening programs give a sort of "snapshot" view of the magnitude of the lead poisoning problem. The rates observed in such programs can be used with greatest confidence only to estimate how many children could be expected to be found by a similar program. One cannot interpret these results to yield a probability over a given length of time that a typical child will have an EBL, because this one-time snapshot view does not yield any information on how blood lead level fluctuates in one child over time. On the other hand, the probability that a child will experience (or has experienced) EBL at some time is undoubtedly greater than that described by the average rate of EBL's observed at one point in time.

2.1.1. Survey of Existing Incidence Data

Table 2 lists several areas reporting lead poisoning cases in the last few years. Many cities and states and the Federal government do not require the reporting of lead poisoning to responsible authorities, thus making an accurate nationwide enumeration of the number of cases impossible. Most of the areas listed in Table 2 do not have active programs screening children, but rather rely on information received from existing medical facilities.

Table 3 lists most of the areas in which any screening program exists and includes comments on the programs. They fall roughly into three categories. The first includes areas where authorities are aware of the problem, but are unable to fund any mass screening effort, and therefore only test children brought into medical facilities such as hospitals or clinics. In some areas testing is done only if the child exhibits symptoms unexplained by other conditions. The second category includes those areas which have limited mass screening of children living in high risk environments. One such effort was carried out by the Bureau of Community and Environmental Management (BCEM) of HEW, and several of the cities listed in Table 3 participated in this BCEM survey. The final category includes cities with true mass screening programs, screening a significant portion of the children who are at greatest risk. Only a few programs,

Table 2

Areas Reporting Lead Poisoning Cases[18]

Baltimore
Boston
Chicago
Cincinnati
Cleveland
Connecticut
Delaware
Denver
Detroit
Dover, Del.
Hartford
Honolulu
Illinois
Kansas City
Louisville
Milwaukee
Nassau County, N.Y.
Newark, N.J.
New Haven
New Orleans
New York City
New York State
Norfolk
Norristown, Pa.
Oklahoma City
Philadelphia
Portland, Maine
Providence
Rochester, N.Y.
St. Louis
Washington, D.C.
Wilmington

Table 3

Current Programs

Area	Number Screened	Year	Description of Program
Baltimore	746	1969	Mostly by physicians or in hospitals
	939	1970	
Buffalo			Small screening effort
Chicago	28008	1967	Mass screening
	40785	1968	
	47527	1969	
	44347	1970	
	28973	1971	
Cincinnati			Small screening effort, test children with symptoms
Columbus			Test children with symptoms
Connecticut:			Using primarily the ALA urine test
Bridgeport			2 cases reported, small screening, also test in clinics
Hartford	147		Test in hospitals and test children with symptoms
New Haven	1897	1970	Mass screening in 1970, not funded in 1971, now screening primarily in hospitals and clinics
Stamford	130		Small screening effort
Waterbury	500		Small screening effort
Delaware:			
Wilmington			BCEM survey, small screening, in hospitals
Denver			Small screening effort.
Illinois:			
Aurora	1708	1971	Mass screening, 12% of all children screened
Springfield	670	1971	Screening in selected areas
Peoria	387	1971	
E. St. Louis	376	1971	
Decatur	763	1971	
Joliet	383	1971	
Rock Island	285	1971	
E. Moline	293	1971	
Robbins	103	1971	
Harvey	226	1971	
Carbondale	264	1971	
Indianapolis			BCEM survey, small screening effort
Kansas City			Testing in hospitals
Massachusetts:			
Boston			Pilot project, initiated by community groups
Cambridge			In hospitals, planning future efforts
Lowell			In clinics
Worcester			Screening in Model Cities areas

Table 3 Continued

Area	Number Screened	Year	Description of Program
Milwaukee			Test children with symptoms
Minneapolis			Test children with symptoms
Nashua, N.H.			BCEM survey
Nashville	97		Pilot project
New Jersey:			
Jersey City			Testing in hospitals, testing children with symptoms
Newark	3048	1971	Some mass screening and also in hospitals
Paterson			Testing children with symptoms
Trenton			Testing in hospitals
New Orleans	727		Using a finger prick test
New York City	2648	1969	Mass screening
	84368	1970	
	87559	1971	
Norfolk	About 1200	1971	Grant from BCEM to conduct small screening
Omaha			Small screening effort
Philadelphia	About 5000		Screening in Model Cities Areas, testing in hospitals and clinics, not using blood lead test
Portland, Maine	About 1000	1970	Small screening effort, testing in hospitals, using ALA urine test
Portland, Ore			BCEM survey
Rhode Island	2600		Screening using hair samples
Rochester, N.Y.			Screening, also test children with symptoms
Sacramento			BCEM survey, small screening effort
St. Louis	4027	1971	Mass screening in selected areas
San Antonio			Test children with symptoms
San Francisco			Small screening effort
Salt Lake City			BCEM survey
South Bend			Small screening effort
Syracuse			Small screening effort, test children with symptoms
Washington, D.C.	808	1970	Small screening effort and testing in clinics
	1821		
Yonkers			Small screening effort, test children with symptoms

such as those in Chicago, New Haven, Aurora, New York, and St. Louis fall into this category. Several screening programs use test methods other than blood lead determinations, such as the ALA urine test or the determination of the lead content of hair clippings.

Table 4 gives the distribution of blood lead levels (measured in μg/100 ml) of children screened by the major programs, and the total number of children screened by each program in the time period indicated. None of these programs occurs west of the Mississippi River, and only New Orleans and Norfolk are in the South. Most programs have tested children once, in a small pilot effort. Only New York and Chicago have allotted funds for continuing screening programs, testing and retesting children in the same areas year after year.

Table 5 lists the percentages of screened children found to have EBL in each of the programs. The first column records the percentage for each recording year and the second column gives the average percent for each program. The percentages range from a low of 6.1 in Washington in 1970 to a high of 46.3 in New York in 1969. The screening of children in New York in 1969 differed from the screening there in 1970, in that in 1969 sick children were screened in hospitals and clinics, while in 1970 the screening program used a community outreach approach to screen in areas having large concentrations of poor quality housing. The Illinois State survey found EBL percentages varying from a low of 9.5 in Rockford to a high of 31.3 in Peoria, indicating considerable difference in rates in different cities.

Table 4

Distribution of Blood Lead Levels for Several Programs

Blood Lead Level	New York 1969	New York 1970	New York 1/1/71- /71	Newark 1971	Norfolk 1970-1971	St. Louis 1970	St. Louis 1/71-11/71	Wash-ington D.C. 1970	Wash-ington D.C. 4/26-10/29	New Orleans 1971	New Haven 1970	Baltimore 1968	Baltimore 1969	Baltimore 1970
0- 9	0.0	0.0	0.0	2.0	75.9	62.7	71.2	.2	60.8	71.5	77.1	74.7	72.1	68.5
10-19	5.9	6.0	6.2	15.0				29.9						
20-29	20.8	31.6	38.3	30.8				45.1						
30-39	27.8	33.7	31.8	26.7				18.3						
40-49	21.8	16.1	13.4	14.7	17.6	17.9	21.3	4.6	22.5	23.5	8.7	19.7	20.7	16.9
50-59	12.0	6.6	5.7	6.4				1.5	9.1		6.8			7.3
60-69	5.9	3.3	2.7	1.9	6.5	19.4	5.8	0.0		3.4	3.8	3.5	4.4	6.0
70-79	6.6	2.7	1.9	.6							1.3			
80-89				1.8					7.6	1.1	1.0	2.1	2.8	1.4
90-99											.6			
100$^+$										.4	.7			
Number Screened	2648	84368	87559	3052	877	1021	4027	808	1821	727	1339	665	746	939
Source	Lead Poisoning Control Bureau, City of New York, Guinee			Draft - HUD Report to Congress							New Haven Lead Paint Poisoning Program - Whitmire	Lin-Fu, PHS-HEW, "Undue Absorption of Lead Among Children--A New Look At An Old Problem"		

Table 4 Continued

Blood Lead Level	Chicago 1968	Chicago 1969	Chicago 1970	Chicago 1/71-5/71	Aurora Ill. 1971	Spring-field, Ill. 1971	Peoria Ill. 1971	E. St. Louis, Ill. 1971	Deca-tur, Ill. 1971	Joliet Ill. 1971	Rock Island Ill. 1971	E. Moline Ill. 1971	Robbins Ill. 1971	Harvey Ill. 1971	Carbon-dale, Ill. 1971	Rock-ford, Ill. 1971
0- 9	88.5	93.3	91.6	91.5	14.3	69.9	68.7	75.3	87.8	75.7	78.9	88.6	87.4	83.6	83.0	90.5
10-19					22.5											
20-29					26.7											
30-39					17.0											
40-49	7.7	5.2	6.4	7.1	10.3	14.1	13.5	12.7	6.7	13.3	8.1	6.7	9.7	7.1	11.7	5.0
50-59					4.1	8.9	8.8	7.2	2.7	7.9	6.3	2.7	2.9	6.2	3.8	2.8
60-69	3.8	1.5	2.0	2.4	1.7	3.1	5.9	2.9	1.9	2.1	2.1	2.0	0.0	1.3	.4	.8
70-79					1.0	3.0	1.5	1.4	.1	.2	3.5	0.0	0.0	.9	.7	.3
80-89					.7	.3	1.3	.2	.5	0.0	1.1	0.0	0.0	.5	.4	.1
90-99					.3	.4	0.0	.3	.3	.3	0.0	0.0	0.0	.4	0.0	0.0
100+					.5	.3	.3	0.0	0.0	.5	0.0	0.0	0.0	0.0	0.0	.1
Number Screened	40785	47527	44347	14821	1707	670	387	793	383	285	298	103	226	264	264	1200
Source	Draft - HUD Report to Congress				Kane Co. Council on Economic Opportunity, Tollaksen	Fine and Suhs, "Pediatric Lead Poisoning In Illinois"										

Table 5
Percent with Elevated Blood Lead Levels of Those Screened in Several Programs

	% EBL	% EBL Program Average
New York 1969	46.3	32.9
New York 1970	28.7	
New York 1/71-8/71	23.7	
Newark	25.4	25.4
Norfolk	24.1	24.1
St. Louis 1970	37.3	32.2
St. Louis 1/71-11/71	27.1	
Washington 1970	6.1	22.6
Washington 4/26-10/29, 1971	39.2	
New Orleans	28.4	28.4
New Haven	22.9	22.9
Baltimore 1968	25.3	28.2
Baltimore 1969	27.9	
Baltimore 1970	31.5	
Chicago 1968	11.5	8.8
Chicago 1969	6.7	
Chicago 1970	8.4	
Chicago 1/71-5/71	8.5	
Aurora	23.6	19.4
Springfield	30.1	
Peoria	31.3	
E. St. Louis	24.7	
Decatur	12.2	
Joliet	24.3	
Rock Island	21.1	
E. Moline	11.4	
Robbins	12.6	
Harvey	16.4	
Carbondale	17.0	
Rockford	9.5	
Average	22.7	26.1

2.1.2. Criteria for Choice of Incidence Data Sources

Several criteria were used in evaluating various sources of incidence data.

1. The data should be acquired from an area with a mass screening program.
2. The data must be in a form which can be readily aggregated by the same geographical zonal system as the demographic data and as that required for model output.
3. Incidence data should be determined by blood lead level test.

Data obtained from general mass screening are obviously more likely to yield incidence rates characteristic of the population of an area than are rates derived from samples with any kind of systematic bias. Assured representativeness of data from mass screening is required to permit accurate extrapolations from the small samples to incidence rates for area wide populations.

It is necessary that the geographic level of aggregation of the incidence data be compatible with that for the demographic data, described below in section 2.2. Most incidence data sources do not themselves have their data already aggregated by any zonal system, but have only the home address of each child tested, together with blood lead level and other information needed by the program. In many instances these data are not yet in machine readable form but appear on handwritten file cards. Even computer coded data which have no zonal classification other than the street address must be further processed by hand to obtain zone numbers, since the present state of the art of computerized address coding is quite rudimentary and still experimental.

The third criterion required of the incidence data is that they result from a macro-blood lead determination. In section 1.1.4. we discussed testing methods and cited the Surgeon General's recommendation that the primary testing method be the blood lead test. Although micro-analysis procedures are available to analyze the amount of lead in small samples of blood obtained by finger pricks, the experience of several experts has been that the risk of the contamination of such samples is very great. Therefore we have restricted our data sources to those using a macro-blood lead test to screen.

2.1.3. Selected Sources of Incidence Data

Criteria 1 and 3 of section 2.1.2 and project time restrictions limited the potential data sources to the four listed in Table 6. The volume of data requiring hand coding of addresses precluded the use of the Chicago or New York data in the modeling effort described in this report. Thus the two data sources from which data were used for developing, calibrating, and validating the lead paint poisoning model are New Haven, Connecticut, and Aurora, Illinois.

When this study began the New Haven data were the only ones immediately available already aggregated by an appropriate zonal system. The city of

Table 6

Incidence Data Sources

Source	Form	Comments
New Haven	published report	already aggregated by census tract
New York	magnetic tape	only has addresses, large amount to process
Chicago	file cards	only has addresses, must be coded, large amount to process
Aurora, Illinois	forms	only has addresses, need to process fewer than 2000 forms

New Haven conducted a mass screening program in 1970, testing 1897 children; funding was not available to continue this in 1971, so that for this year only children brought into hospitals or clinics were tested. Some of the children tested in 1970 received only an ALA urine test and no follow-up blood test. These children were omitted from the data set, leaving about 1300 tests which were used in model development and calibration. This represents about 3 percent of New Haven children six years old or younger.

In July of 1971 the Illinois Department of Public Health tested 449 children in Aurora, Illinois. Subsequently the Kane County Council of Economic Opportunity screened an additional 1258 high risk children making a total of 1707 tests, representing 12.8% of all children in Aurora. These data were originally recorded on forms which contained additional information about the child and his family. Since the only geographical information available on each child was a street address, it was necessary to code a zone for each address as well as to code the other information prior to committing it to punched cards. Whereas the New York and Chicago data sets were too large to permit this type of hand coding, project time and budget constraints did allow the hand processing of the smaller Aurora data set.

Both the New Haven and Aurora data contained some bias, since both focused their programs on testing "high risk children", those living in neighborhoods containing poor quality old housing which is likely to contain peeling lead. No current program has tested a random sampling of children; all have concentrated on testing only those children running the greatest risk of poisoning. The definition of "high risk" is, however, vague (or often not stated at all), making difficult an exact characterization of those children screened in relation to the total population of children.

2.2. Demographic Data

The lead poisoning model will relate the incidence of EBL in an area to demographic characteristics of that area. The demographic factors which have been associated with lead poisoning, in the literature and in conversations with experts, can be divided into two types: 1) those concerned with the environment in which the lead poisoned child lives, and 2) those concerned with the socio-economic characteristics of the child's family.

2.2.1. Demographic Characteristics Associated with Lead Poisoning

Table 7 lists some of the housing data items which have been associated with lead poisoning. The most obvious characteristic of the housing in which a lead poisoned child lives is the presence of lead paint in a form the child can easily ingest. Until the 1940's lead paint was the predominantly used wall covering house paint in this country. Subsequently lead paint usage declined as latex paints were introduced. In 1955 the American Standards Association (now ANSI) adopted a voluntary standard prohibiting interior house paint from containing more than 1% lead by weight, and requiring a message cautioning against use

Table 7

Housing Characteristics for Use in a Lead Paint Poisoning Model

1. the number[19] of units currently standing which were built in various periods
    a. built before 1940
    b. built between 1940 and 1950
    c. built between 1950 and 1960
2. the number of sound[20] housing units
3. the number of dilapidated housing units
4. the number of deteriorating housing units
5. the median dollar value of owner occupied housing units
6. the average monthly contract rent
7. the housing vacancy rate
8. the number of multiple unit structures
9. the number of renter occupied units
10. the number of renter occupied units

on surfaces accessible to children to be printed on the label of all leaded paints. However, recent surveys[21] have found some leaded paints on the market to lack adequate cautionary labeling. In addition, lead exterior paints are still sold and children may eat paint chips from exterior railings, porches, garages, exterior windowsills, and accessible exterior walls. Therefore, some walls being painted today may well offer a potential hazard to children in the future. It is impossible to set a cutoff date for which one can say housing built before that time is probably hazardous and housing built later is probably not. Without a major survey of housing, one can only speculate on the fraction of housing built in any year which has lead paint in it.

In the absence of more definitive information on the correlation between the age of a dwelling and the presence of lead paint, it may be necessary to use the condition of the dwelling unit. This may actually be a more reliable indicator, since lead paint on a surface does not necessarily offer an immediate hazard to a child if the surface has been well maintained, paint is not chipping or peeling, and the surface does not present a chewable edge to the child. Such surfaces are, of course, a potential hazard, since if the dwelling unit is allowed to deteriorate, at some future time peeling and chipping paint may provide a source of lead for a child to ingest.

Other items listed in Table 7 may be used to identify poor people living in unsound housing (those running the greatest risk of lead poisoning). Presumably such housing is lower in value, and monthly rent for such housing is lower than rental costs for better quality housing in the same area. (It should be noted, however, that inner city rents for poor quality housing are sometimes higher than rents for better quality suburban units.) Vacancy rates for such units are usually higher than rates for better quality housing. Lead poisoning is found primarily among the poor, who are usually unable to own their own housing. Thus the number of owner occupied versus rental units is of interest, as is the number of multiple unit structures (which are most often rental units) versus single unit structures.

Table 8 lists population characteristics associated with lead poisoning. All but a small number of reported cases have occurred in children six years old or younger, and most programs concentrate their testing on children in this age range. The children who develop lead poisoning come primarily from poor families, those most likely to be living in deteriorating or dilapidated housing. Many of the characteristics listed in Table 8 are associated with such families. They live under crowded conditions, a disproportionate number of the families are headed by females, many of the families are newly arrived to the city from the rural South, the head of the household often has not completed high school, the household head if employed at all works in a menial job, and finally a disproportionate number of such families belong to minority groups. Of course, not all children with lead poisoning belong to families with all or most of these characteristics, but one can often identify neighborhoods which contain high risk children as those in which many families do fall into these categories.

Table 8

Population Characteristics for Use in a Lead Paint Poisoning Model

1. the number[22] of children in various age categories
    a. under 5
    b. 5 years old
    c. 6 years old
2. the median family income
3. the number of families with incomes below the poverty level
4. the number of people living under crowded conditions
    a. crowded $\geq$ 1.01 persons per room
    b. crowded $\geq$ 1.51 persons per room
5. the number of female household heads
6. the distribution[23] of region of birth of the household head
7. the distribution, by years of school completed, of the educational level of the household head
8. the distribution of the work status (employed or unemployed, job category) of the head of household
9. the distribution of persons by race

2.2.2. Sources of Demographic Data

There are basically two sources of the types of data listed in Tables 7 and 8, namely the U. S. Census Bureau and various local data sources such as property tax records and welfare agency files. It was decided to use data available from the U. S. Census Bureau rather than those from local sources, for three reasons:

1) Census data are of uniform type and quality across the country.
2) The reputation and resources of the Census Bureau make it likely that Census reports have the greatest possible accuracy subject to criterion 1.
3) The Census data were available on computer magnetic tape from virtually a single source. Their use did not necessitate a search of possible sources and separate evaluation and reconcilation of the form and quality of each.

Although the 1970 Census was conducted 2 years ago, not all the data then collected were released in time to be used in this effort; one main data item, the distribution of housing by condition of house, was not collected in 1970. Therefore it has been necessary to investigate the availability of data from 3 different Census sources: the 1970 Fourth Count, the 1970 First Count, and the 1960 Census.

The 1970 Census had 3 levels of sampling; one included questions asked of all persons, a second was asked of 15 percent of the population, and a third was asked of only 5 percent. The Census First Count data includes responses only from the 100 percent sampled questions, which do not include questions concerning the age of the dwelling unit, the family income, or the region of birth, educational level, or work status of household head, all of which appear in the Fourth Count data. In addition, the Census Bureau discontinued questions concerning the condition of the dwelling unit after the 1960 Census, because of the subjectiveness and lack of uniformity encountered in interpreting the definitions of sound, deteriorating and dilapidated. Therefore, the data used by this project which concerned condition of housing were taken from 1960 Census published reports. 1970 Fourth Count data were not released in time to be utilized. Thus the 1970 Census First Count was the primary data source for current population and housing statistics, and 1960 Census data were used whenever 1970 data had not yet been released.

2.2.3 Zonal System

The decision to use data from the U. S. Census Bureau means that the zonal system used in the modeling process must be compatible with that of the Census. Several levels of aggregation are available:

1. the block group (in urban areas) and its rural equivalent, the enumeration district,
2. the census tract,
3. the county, and
4. the Standard Metropolitan Statistical Area (SMSA).

There are approximately 250,000 block groups, 50,000 census tracts, 3000 counties, and 243 SMSA's in the U.S. A census tract contains approximately 4000 to 5000 people and consists of about 4 to 6 block groups. An SMSA is a metropolitan area consisting essentially[24] of a central city of at least 50,000 people together with its surrounding suburbs.

It was decided to use census tract level data for model development and calibration, because 1) incidence data were available for only a few cities so that to obtain enough data it was necessary to use a level of aggregation lower than city wide and 2) census tract data are more easily available than block group data, and there are fewer census tracts so the data set is more manageable.

The SMSA level of aggregation was chosen for national predictions. County level was rejected because 1) there are too many counties to code the data and display them effectively, 2) different states have different size counties, and 3) all available incidence data are for urban populations, and it is not known whether the model can predict as well in rural areas. SMSA predictions could be done in two ways: 1) predict for each census tract on the basis of the characteristics of the tract and aggregate to the whole SMSA or 2) predict for the whole SMSA on the basis of aggregate and averaged variables. This second method was used because of the volume and cost of obtaining data for the first procedure.

2.3. Current Data Deficiencies

Current data lack information of several types. Most experts involved in lead poisoning programs believe that the greatest source of poisoning is peeling and chipping lead paint. However, there is little actual data to indicate the fraction of cases caused by paint as opposed to other sources. At present there are no data to establish a relationship between the age of housing in a particular area and the presence of lead paint in the housing. The arbitrary cutoff year 1940 has been used by some as the year after which lead paint was not used, but paint production figures indicate a substantial amount of lead paint was used well into the 1950's. Therefore some housing built after 1940 may and very likely will contain lead paint.

Current incidence data apply primarily to inner city poor children from the East and Midwest. EBL rates for middle class children, for rural and suburban children, and for children living in the South and West are unknown. It is generally believed that rates for these children are lower than for the Eastern urban poor,[25] but screening of these groups is needed to establish the magnitude of that rate difference.

The demographic data available for the modeling effort described in this report were lacking in two respects, namely the late release of the Census Fourth Count data and the lack of 1970 housing condition data. The first of these deficiencies has been remedied (but too late for this modeling effort), since the Fourth Count data have now been released. The lack of housing condition data can also be remedied through the use of a model developed by the Census Bureau to predict the distribution of housing, by condition of unit, from Census Fourth Count data.

3. THE MODELS

3.1. Aggregation Problems

The word "aggregation", in the context of a statistical study or the construction of a mathematical model, refers to the way the subjects of the study or model are grouped in the analysis or subsequent application. The degree to which subjects, populations or observations are combined is called the level of aggregation. Problems may arise when one level of aggregation is used for model calibration and another for model application.

Difficulties and costs in obtaining and processing data for 50,000 census tracts, rather than 250 SMSA's, discouraged using the census tract level of aggregation for the estimation of the national incidence of lead paint poisoning. On the other hand, incidence data were not available from enough different areas all at one level of aggregation, such as the city, to calibrate a model at a higher level of aggregation than that of the census tract. The data described in section 2.1 are most often available for selected sections of a city rather than the whole city. Thus it was decided to calibrate the model at the census tract level, but to apply it at the SMSA level. On the basis of this decision, model evaluation included steps to check for possible aggregation problems.

Problems of different levels of aggregation may arise whenever the form of the model is non-linear (that is, not strictly proportional to a sum of variables). For example, suppose the incidence I of lead poisoning could be calculated by the formula

$$I = \sqrt{K} ,$$

where K is the number of children in the area. Consider a region containing 25 children. The formula predicts 5 victims of lead poisoning. If the same region is broken into 2 sub areas, one containing 16 children and the second containing 9, the predicted incidence for the first area would be 4 and for the second area 3, making a total of 7 for the whole region, a difference of 40% from the original estimate.

Problems may also arise if the variables are non-linearly related to the populations they represent. Data expressed as medians or rankings are examples of such types of variables. Suppose, for instance, that the fraction L of housing containing lead is related to the median age A of housing in an area, by the formula

$$L = \begin{cases} .02A & \text{for } A \leq 50 \\ 1.0 & \text{for } A > 50 \end{cases}$$

Suppose one area has 20 houses all 50 years old, and an adjacent area has 10 houses all 10 years old. The median age of housing in the first area is 50 years, so the fraction of housing there having lead is 1, i.e., all 20 houses contain lead. In the second area the median age is 10 years, so that the fraction of housing containing lead is .2, or 2 houses. The total number of houses in the two areas which would contain lead, if one calculates for the two areas separately, is 20 + 2 or 22. If one considers the whole region as one area containing 30 houses, 10 of which are 10 years old and 20 of which are 50 years old, the median age is 50 years. On this basis 100 percent of the housing, or 30 houses should contain lead, an increase of 36 percent over the first method of calculation.

Higher levels of aggregation may exhibit a homogeneity among areas, which does not exist at lower levels. For instance, median as well as mean incomes may vary markedly between poor and rich neighborhoods, whereas the median (or mean) incomes for different metropolitan areas do not. Therefore data at the higher level of aggregation may not vary enough to discriminate among levels of occurrence of phenomena. On the other hand, the tendency towards homogeneity at higher levels of aggregation may be an advantage if there are compensating errors. An example of this occurs in the current work where because of the late release of some of the 1970 housing data, it was necessary to employ 1960 data for the distribution of housing by age. Whereas the fraction of housing built before 1940 and still standing in 1960 may be very different because of a concentration of urban renewal projects from that still standing in 1970 in a single census tract, the total amount of housing torn down in renewal projects over the whole SMSA during the last 10 years is a small fraction of either the total housing or the pre-1940 housing and thus will have much less affect on these figures.

3.2. Analysis of the New Haven Data

Table 9 contains demographic and screening data by census tract for the city of New Haven. The demographic data items tabulated include 1970 population, the number of children six years old or less, the number of female household heads, the number of people living in crowded households with more than 1 person per room, or again with more than 1 1/2 persons per room, the total number of housing units, and the number of rented

Table 9

New Haven Data

Census Tract	Number of Children Screened	Number of EBL's Found	Total Population (1970)	Children 6 and Under (1970)	Female Household Heads (1970)	Population Crowded ≥ 1.01/room (1970)	Population Crowded ≥ 1.51/room (1970)	Median Family Income (1960)	Total Housing (1960)	Deteri- orating Units (1960)	Dilapi- dated Units (1960)	Units Built Before 1940 (1960)	Total Housing (1970)	Rental Units (1970)
1401	1	0	1147	78	44	161	60	4984	889	520	20	889	473	404
1402	4	1	273	22	16	40	7	5036	393	39	48	393	88	51
1403	124	36	4724	566	384	1190	378	5288	1677	393	171	1642	1376	930
1404	36	13	3478	464	61	609	148	5924	1235	43	12	1231	1218	781
1405	141	48	5166	887	457	1636	401	5983	1921	1001	30	1909	1611	1084
1406	321	122	7987	1512	984	2388	624	4986	2862	1151	189	2831	2619	1964
1407	49	12	6593	377	512	702	206	5114	4069	875	250	3985	3839	3327
1408	9	1	4316	445	270	510	127	5982	1942	145	73	1867	1565	1163
1409	5	0	4421	335	204	164	27	6825	2020	59	2	1910	1992	1441
1410	0	0	4346	349	156	135	58	8427	1568	140	0	1323	1638	713
1411	0	0	3019	232	65	23	0	10804	864	2	0	167	1037	274
1412	46	3	5765	727	283	969	183	6346	1748	27	1	732	2024	1089
1413	102	9	5477	576	351	1296	200	5492	1054	24	0	459	1577	1330
1414	1	1	5024	431	204	409	114	7776	1776	79	5	1476	1852	946
1415	135	33	9121	1370	1052	2238	506	5670	3000	773	47	2925	3018	1909
1416	100	22	7283	1233	1303	1872	291	3848	3152	725	306	2303	2435	1913
1417	0	0	5218	136	30	159	38	5087	730	166	0	721	594	494
1418	19	9	4715	645	232	491	74	6865	1516	167	51	1009	1658	1255
1419	2	0	5617	490	249	379	62	7042	2388	108	4	2310	2444	1633
1420	0	0	3736	198	146	291	65	6099	2036	376	150	2024	1902	1449
1421	54	9	2207	379	350	748	142	4183	1726	220	204	1453	772	619
1422	2	2	2165	226	110	297	66	4729	1771	643	127	1765	885	671
1423	95	17	5127	660	352	996	230	5611	2010	364	16	1986	1921	1255
1424	109	21	5151	708	300	1057	191	5755	2377	232	14	2361	1925	1293
1425	29	8	5512	786	334	985	157	5916	2095	264	79	1788	1942	1266
1426	4	1	8545	1205	269	1547	301	6683	1803	168	21	1002	2646	1208
1427	0	0	5402	618	194	488	76	6486	1446	105	13	1232	1952	1032
1428	0	0	6051	578	157	449	30	7308	1392	38	9	807	1890	419
Total	1388	368	137586	16233	9069	22229	4762		51460	8847	1842	44500	48873	31913

units. In addition to these 1970 data, 1960 data are included for median family income, total housing, the number of deteriorating housing units, the number of dilapidated housing units, and the number of units standing in 1960 which were built before 1940.

Figure 1 is a map of the census tracts in New Haven, with high and low incidence tracts indicated by heavy dotted areas and diagonal lines respectively. The 14 tracts in which fewer than 10 children were screened are left blank. The New Haven program concentrated screening in neighborhoods which had older housing in poor condition, thus offering an immediate lead hazard, so that presumably those tracts in which few children were screened are lower risk areas.

There are two observations which should be made about the demographic data in Table 9. Between 1960 and 1970 the total number of housing units declined in 17 of the 28 census tracts, and the net decline for all tracts was about 2500. It is not expected that this is typical of most SMSA's, since in general the number of housing units built in the decade from 1960 to 1970 is greater than the number demolished, leading to a net rise in the total number of housing units.

A second observation is that 86.5 percent of the 1960 New Haven housing stock was built before 1940. This is probably representative of the older cities in the Northeast, but much less so of those in the West which sustained their major growth in the post-World War II period. Table 10 lists the percent of 1960 housing stock built before 1940 for each of the 14 census tracts in which more than 10 children were screened. In only 4 out of the 14 tracts is less than 80% of the housing pre-1940,

Figure 1

New Haven Census Tracts

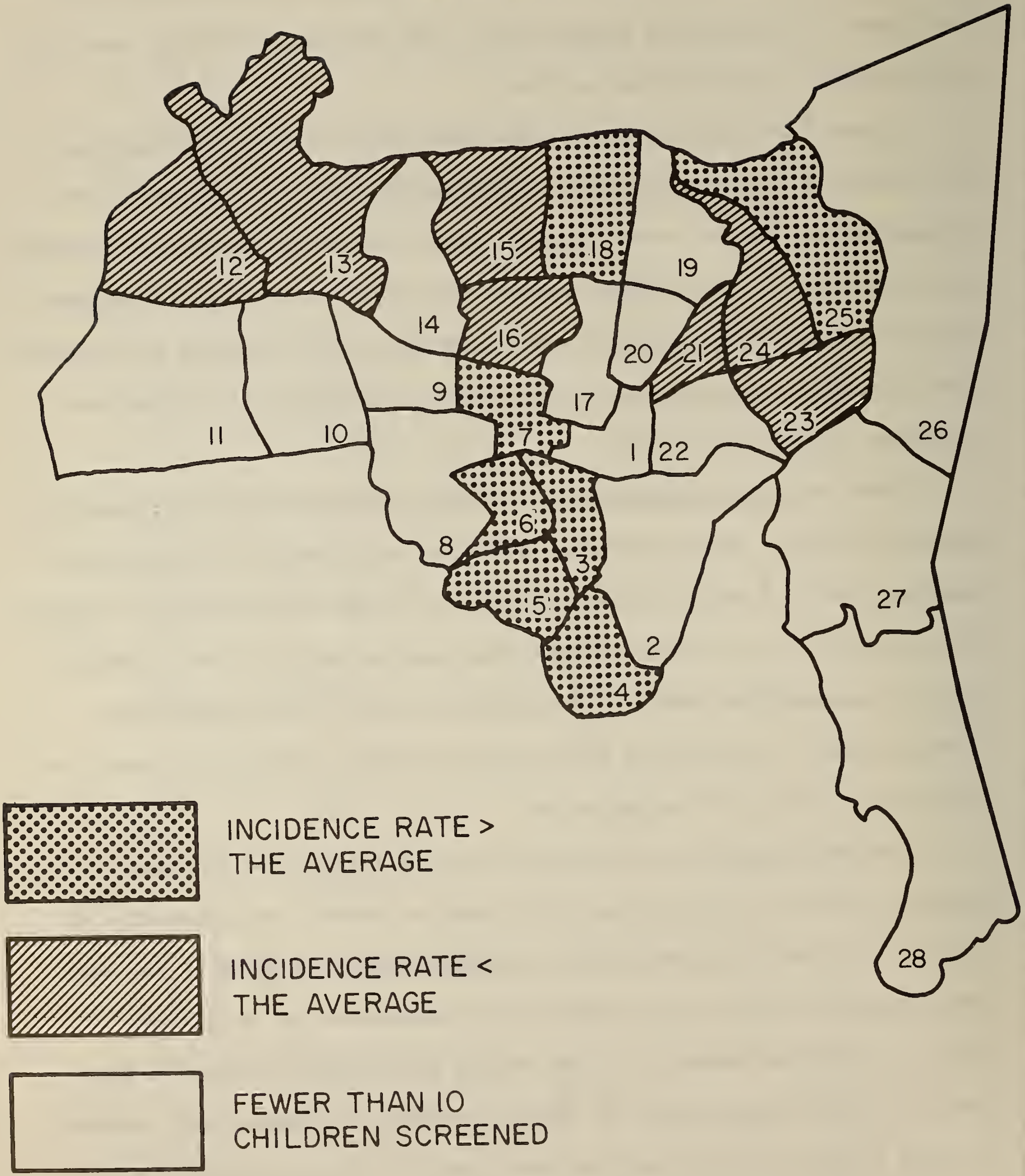


Table 10

Percentage of Housing Built Before 1940 for Census Tracts in Which More Than Ten Children Were Screened

Tract	Percent Built Before 1940
1403	97.9
1404	99.7
1405	99.4
1406	98.9
1407	97.9
1412	41.9
1413	43.5
1415	97.5
1416	73.1
1418	66.6
1421	84.2
1423	98.8
1424	99.3
1425	85.3

and in 8 of the tracts the percent is greater than 97%. Thus, although it was hoped that the fraction of housing stock built before 1940 could be used in the model to differentiate the lead hazard in different regions of the United States, the values of this variable in New Haven do not differ enough to discriminate high and low risk areas.

Tables 11 and 12 give the simple correlation coefficients[26] and Tables 13 and 14 the Spearman rank correlation coefficients[27] calculated on the tract data for New Haven. Tables 11 and 13 are calculated using the values of the variables themselves and Tables 12 and 14 are calculated using the logarithms of the variables. A correlation coefficient of ±1 in all tables indicates the two variables in question differ at most by a constant scale factor, while a coefficient of 0 indicates there is no discernable relationship between the two variables.

The analysis of the correlations is used in the modeling process in three ways. The first of these is the isolation of the most promising predictor variables. The column labeled "Fraction of children screened having EBL" gives the correlation coefficient between the dependent variable and each of the independent variables. Those with the highest numbers (in absolute value) are most closely related to the incidence of EBL and are most likely candidates for good predictor variables. As can be seen from Tables 11 through 14, the characteristics most correlated with the incidence of EBL are the age and condition of housing.

A second way correlations can be used is to avoid fitting error. If two (or more) of the model parameters are assumed to vary independently, whereas in fact they are highly correlated, spurious parameter values may

Table 11

Simple Correlation Coefficients for Selected Variables

	Fraction of Population ≤ 6 Years Old	Fraction of Population as Female Household Head	Fraction of Households Headed by Females	Fraction of Population Crowded ≥ 1.01 Per Room	Fraction of Population Crowded ≥ 1.51 Per Room	Fraction of Housing Which is Rented	Fraction of Housing Which is Deteriorating	Fraction of Housing Which is Dilapidated	Fraction of Housing Which is Unsound	Fraction of 1960 Housing Stock Built Before 1940	Fraction of Children Screened Having EBL	Population	Number of Children ≤ 6 Years Old	Median Rent	Median Family Income
Fraction of Population ≤ 6 Years Old	1.0000	.5239	.6234	.7095	.4869	-.2141	.4438	.2274	.4601	.1536	.2694	.0554	.6234	-.3669	-.2393
Fraction of Population as Female Houaehold Head	.5239	1.0000	.9728	.6648	.4297	.4030	.4490	.7122	.5899	.0922	-.1124	.2889	.4797	-.3394	-.8428
Fraction of Households Headed by a Female	.6234	.9728	1.0000	.7615	.5147	.3186	.4623	.6696	.5909	.0387	-.0923	.2752	.5404	-.3499	-.7880
Fraction of Population Crowded ≥ 1.01 Per Room	.7095	.6648	.7615	1.0000	.8230	.0658	.5221	.3917	.5733	.1899	-.1203	-.0222	.3744	-.6553	-.5621
Fraction of Population Crowded ≥ 1.51 Per Room	.4869	.4297	.5147	.8230	1.0000	-.0588	.7000	.3958	.7353	.4905	.1395	.0398	.3124	-.6307	-.3775
Fraction of Housing Which is Rented	-.2141	.4030	.3186	.0658	-.0588	1.0000	.0755	.4679	.1890	-.0675	.0584	-.0243	-.1688	.0997	-.5266
Fraction of Housing Which is Deteriorating	.4438	.4490	.4623	.5221	.7000	.0755	1.0000	.2471	.9683	.5482	.4329	.3988	.5476	-.3774	-.2110
Fraction of Housing Which is Dilapidated	.2274	.7122	.6696	.3917	.3958	.4679	.2471	1.0000	.4815	.1946	.1427	-.1240	.0089	-.2326	-.7465
Fraction of Housing Which is Unsound	.4601	.5899	.5909	.5733	.7353	.1890	.9683	.4815	1.0000	.5460	.4283	.3287	.4976	-.4014	-.3834
Fraction of Housing Stock Built Before 1940	.1536	.0922	.0387	.1899	.4905	-.0675	.5482	.1946	.5460	1.0000	.4708	.0536	.1246	-.6376	-.1631
Fraction of Children Screened Having EBL	.2694	-.1124	-.0923	-.1203	.1395	.0584	.4329	.1427	.4283	.4708	1.0000	.0218	.2007	.1633	.2693
Population	.0554	.2889	.2752	0.0222	.0398	-.0243	.3988	-.1240	.3287	.0536	.0218	1.0000	.8085	.1052	-.0837
Number of Children ≤ 6 Yesrs Old	.6234	.4797	.5404	.3744	.3124	-.1688	.5476	.0089	.4976	.1246	.2007	.8085	1.0000	-.1190	-.1724
Median Rent	-.3669	-.3394	-.3499	-.6553	-.6307	.0997	-.3774	-.2326	-.4014	-.6376	.1633	.1052	-.1190	1.0000	.5153
Median Family Income	-.2393	-.8428	-.7880	-.5621	-.3775	-.5266	-.2110	-.7465	-.3834	-.1631	.2693	-.0837	-.1724	.5153	1.0000

Table 12

Simple Correlation Coefficients for Logarithms of Selected Variables

	Fraction of Population ≤ 6 Years Old	Fraction of Population as Female Household Heads	Fraction of Households Headed by Females	Fraction of Population Crowded ≥ 1.01 Per Room	Fraction of Population Crowded ≥ 1.51 Per Room	Fraction of Housing Which is Rented	Fraction of Housing Which is Deteriorating	Fraction of Housing Which is Dilapidated	Fraction of Housing Which is Unsound	Fraction of 1960 Housing Stock Built Before 1940	Fraction of Children Screened Having EBL	Population	Number of Children ≤ 6 Years Old	Median Rent	Median Family Income
Fraction of Population ≤ 6 Years Old	1.0000	.2967	.4633	.6738	.3840	-.2892	.2462	-.1000	.2546	.1125	.2131	-.0968	.5965	-.3774	-.1601
Fraction of Population as Female Household Head	.2967	1.0000	.9631	.5544	.4306	.4037	.6142	.4028	.6390	.1110	-.0412	.2548	.4056	-.2987	-.7180
Fraction of Households Headed by a Female	.4633	.9631	1.0000	.6938	.5067	.3122	.5550	.4311	.5747	.0363	-.0544	.2205	.4903	-.3178	-.6651
Fraction of Population Crowded ≥ 1.01 Per Room	.6738	.5544	.6938	1.0000	.8432	-.0163	.3162	.2489	.3219	.1632	-.0959	-.0998	.3741	-.6981	-.5153
Fraction of Population Crowded ≥ 1.51 Per Room	.3840	.4306	.5067	.8432	1.0000	-.0614	.4826	.1453	.4767	.4545	.0895	-.0341	.2315	-.7273	-.4221
Fraction of Housing Which is Rented	-.2892	.4037	.3122	-.0163	-.0614	1.0000	.2456	.8389	.3008	.0235	.1640	-.0755	-.2560	-.0657	-.5340
Fraction of Housing Which is Deteriorating	.2462	.6142	.5550	.3162	.4826	.2456	1.0000	.2122	.9863	.7430	.6575	.2897	.3997	-.4437	-.3271
Fraction of Housing Which is Dilapidated	-.1000	.4028	.4311	.2489	.1453	.8389	.2122	1.0000	.2656	-.0287	.1428	-.0599	-.1157	-.0546	-.4992
Fraction of Housing Which is Unsound	.2546	.6390	.5747	.3219	.4767	.3008	.9863	.2656	1.0000	.7451	.6720	.1793	.3164	-.4526	-.4112
Fraction of Housing Stock Built Before 1940	.1125	.1110	.0363	.1632	.4545	.0235	.7430	-.0287	.7451	1.0000	.7161	-.0148	.0639	-.6385	-.1578
Fraction of Children Screened Having EBL	.2131	-.0412	-.0544	-.0959	.0895	.1640	.6575	.1428	.6720	.7161	1.0000	.0373	.1739	-.1092	.0786
Population	-.0968	.2548	.2205	-.0998	-.0341	-.0755	.2897	-.0599	.1793	-.0148	.0373	1.0000	.7411	.2333	.0642
Number of Children ≤ 6 Years Old	.5965	.4056	.4903	.3741	.2315	-.2560	.3997	-.1157	.3164	.0639	.1739	.7411	1.0000	-.0664	-.0563
Median Rent	-.3774	-.2987	-.3178	-.6981	-.7273	-.0657	-.4437	-.0546	-.4526	-.6385	-.1092	.2333	-.0664	1.0000	.4388
Median Family Income	-.1601	-.7180	-.6651	-.5153	-.4221	-.5340	-.3271	-.4992	-.4112	-.1578	.0786	.0642	-.0563	.4388	1.0000

Table 13

Spearman Rank Correlation Coefficients for Selected Variables

	Fraction of Population ≤ 6 Years Old	Fraction of Population as Female Household Heads	Fraction of Households Headed by Females	Fraction of Population Crowded ≥ 1.01 Per Room	Fraction of Population Crowded ≥ 1.51 Per Room	Fraction of Housing Which is Rented	Fraction of Housing Which is Deteriorating	Fraction of Housing Which is Dilapidated	Fraction of Housing Which is Unsound	Fraction of 1960 Housing Stock Built Before 1940	Fraction of Children Screened Having EBL	Population	Number of Children ≤ 6 Years Old	Median Rent	Median Family Income
Fraction of Population ≤ 6 Years Old	1.0000	.5604	.6747	.6659	.4198	-.0681	.4945	.4066	.4637	.2088	.2571	.1297	.6000	-.5066	-.1780
Fraction of Population as Female Household Head	.5604	1.0000	.9033	.8066	.5956	.4330	.7758	.6703	.7934	.0066	-.0286	.3538	.3143	-.3656	-.7758
Fraction of Households Headed by a Female	.6747	.9033	1.0000	.8945	.6176	.2703	.6264	.5121	.6176	-.1165	-.0945	.2571	.4769	-.3921	-.6264
Fraction of Population Crowded ≥ 1.01 Per Room	.6659	.8066	.8945	1.0000	.8022	.2088	.6000	.4198	.6176	.1780	-.0725	.0681	.3319	-.5991	-.5560
Fraction of Population Crowded ≥ 1.51 Per Room	.4198	.5956	.6176	.8022	1.0000	-.0505	.6527	.3538	.6352	.4681	.1341	-.0549	.1912	-.5683	-.4066
Fraction of Housing Which is Rented	-.0681	.4330	.2703	.2088	-.0505	1.0000	.1473	.4198	.2967	-.1956	.0154	-.0724	-.3978	.0595	-.6000
Fraction of Housing Which is Deteriorating	.4945	.7758	.6264	.6000	.6527	.1473	1.0000	.5780	.9692	.4022	.4374	.3626	.4286	-.3524	-.3934
Fraction of Housing Which is Dilapidated	.4066	.6703	.5121	.4198	.3538	.4198	.5780	1.0000	.6835	.0022	.3626	-.0154	-.0637	-.2423	-.6044
Fraction of Housing Which is Unsound	.4637	.7934	.6176	.6176	.6352	.2967	.9692	.6835	1.0000	.3802	.4462	.2791	.3099	-.3700	-.4769
Fraction of Housing Stock Built Before 1940	.2088	.0066	-.1165	.1780	.4681	-.1956	.4022	.0022	.3802	1.0000	.4725	-.1429	.0198	-.5705	.0286
Fraction of Children Screened Having EBL	.2571	-.0286	-.0945	-.0725	.1341	.0154	.4374	.3626	.4462	.4725	1.0000	-.0769	.1297	.0507	.2176
Population	.1297	.3538	.2571	.0681	-.0549	-.0724	.3626	-.0154	.2791	-.1429	-.0769	1.0000	.6747	.3128	-.2352
Number of Children ≤ 6 Years Old	.6000	.3143	.4769	.3319	.1912	-.3978	.4286	-.0637	.3099	.0198	.1297	.6747	1.0000	-.0485	.0681
Median Rent	-.5066	-.3656	-.3921	-.5991	-.5683	.0595	-.3524	-.2423	-.3700	-.5705	.0507	.3128	-.0485	1.0000	.2930
Median Family Income	-.1780	-.7758	-.6264	-.5560	-.4066	-.6000	-.3934	-.6044	-.4769	.0286	.2176	-.2352	.0681	.2930	1.0000

Table 14

Spearman Rank Correlation Coefficients for Logarithms of Selected Variables

	Fraction of Population ≤ 6 Years Old	Fraction of Population as Female Household Heads	Fraction of Households Headed by Females	Fraction of Population Crowded ≥ 1.01 Per Room	Fraction of Population Crowded ≥ 1.51 Per Room	Fraction of Housing Which is Rented	Fraction of Housing Which is Deteriorating	Fraction of Housing Which is Dilapidated	Fraction of Housing Which is Unsound	Fraction of 1960 Housing Stock Built Before 1940	Fraction of Children Screened Having EBL	Population	Number of Children ≤ 6 Years Old	Median Rent	Median Family Income
Fraction of Population ≤ 6 Years Old	1.0000	.5604	.6747	.6654	.4198	-.0681	.4945	.0681	.4637	.2088	.2571	.1297	.6000	-.5066	-.1780
Fraction of Population as Female Household Head	.5604	1.0000	.9033	.8066	.5956	.4330	.7758	.5780	.7934	.0066	-.0286	.3538	.3143	-.3656	-.7758
Fraction of Households Headed by a Female	.6747	.9033	1.0000	.8945	.6176	.2703	.6264	.5429	.6176	-.1163	-.0945	.2571	.4769	-.3921	-.6264
Fraction of Population Crowded ≥ 1.01 Per Room	.6659	.8066	.8945	1.0000	.8022	.2088	.6000	.4505	.6176	.1780	-.0725	.0681	.3319	-.5991	-.5560
Fraction of Population Crowded ≥ 1.51 Per Room	.4198	.5956	.6176	.8022	1.0000	-.0505	.6527	.2000	.6352	.4681	.1341	-.0549	.1912	-.5683	-.4066
Fraction of Housing Which is Rented	-.0681	.4330	.2703	.2088	-.0505	1.0000	.1473	.7582	.2967	-.1956	.0154	-.0725	-.3978	.0595	-.6000
Fraction of Housing Which is Deteriorating	.4945	.7758	.6264	.6000	.6527	.1473	1.0000	.2396	.9692	.4022	.4374	.3626	.4286	-.3524	-.3934
Fraction of Housing Which is Dilapidated	.0681	.5780	.5429	.4505	.2000	.7582	.2396	1.0000	.3451	-.3363	.0242	.0154	-.2176	.0352	-.6967
Fraction of Housing Which is Unsound	.4637	.7934	.6176	.6176	.6352	.2967	.9692	.3451	1.0000	.3802	.4462	.2791	.3099	-.3700	-.4769
Fraction of Housing Stock Built Before 1940	.2088	.0066	-.1165	.1780	.4681	-.1956	.4022	-.3363	.3802	1.0000	.4725	-.1429	.0198	-.5705	.0286
Fraction of Children Screened Having EBL	.2571	-.0286	-.0945	-.0725	.1341	.0154	.4374	.0242	.4462	.4725	1.0000	-.0769	.1297	.0507	.2176
Population	.1297	.3538	.2571	.0681	-.0549	-.0725	.3626	.0154	.2791	-.1429	-.0769	1.0000	.6747	.3128	-.2352
Number of Children ≤ 6 Years Old	.6000	.3143	.4769	.3319	.1912	-.3978	.4286	-.2176	.3099	.0198	.1297	.6747	1.0000	-.1057	-.6615
Median Rent	-.5066	-.3656	-.3921	-.5991	-.5683	.0595	-.3524	.0352	-.3700	-.5705	.0507	.3128	-.1057	1.0000	.2930
Median Family Income	-.1780	-.7758	-.6264	-.5560	-.4066	-.6000	-.3934	-.6967	-.4769	.0286	.2176	-.2352	-.6615	.2930	1.0000

occur in the process of curve fitting. This may lead to serious misinterpretations of the interactions among variables and of the sensitivity of the dependent variable to changes in the independent variables.

Correlations among observations need not always give cause for alarm. They can be utilized fruitfully to indicate possible substitute variables for unavailable or less desirable (e.g., not well defined or less precise) ones. As an example, we believe lead poisoning to be highest among the poor, and desire to use family income as a determining variable, but current income data were not available in time to be used in the modeling effort. Because of the high correlations (greater than .7 in absolute value in all tables) between 1960 income and the fraction of 1970 population which are female household heads, we have ventured to use the female household head fraction variable as a substitute for income in the modeling effort.

3.3. Model Form

The choice of an initial model structure in the absence of a highly detailed explanatory hypothesis rests on two principal criteria: simplicity and conceptual plausibility. The first affects ease of calibration, and also amenability to modification when (inevitable) improvements in data availability occur. The second is a measure of how comfortable one is with whatever ideas support a given simple formulation.

The two simplest kinds of representation of the dependency of a numerical measure of some phenomenon on the values of a set of others are grouping them additively (called a linear model), or grouping them multiplicatively (called an exponential model). An example of a linear model with 2 independent variables (X_1 and X_2) would be

$$Y = a_0 + a_1X_1 + a_2X_2. \tag{3.1}$$

An exponential model with the same 2 variables would be

$$Y = b_0 \cdot X_1^{b_1} \cdot X_2^{b_2}. \tag{3.2}$$

No attempt at the formulation of a linear model of the incidence of EBL was remotely successful. Thus the models described in this chapter and in Appendix A are all exponential models, in which the EBL incidence rate is estimated by multiplying the relative frequencies of occurrence of suspected causative factors.

In the models described below, several parameters (the b's of equation 3.2) must be estimated; this procedure is called curve fitting. The standard procedure involves the least squares approximation to the linear form. The model form chosen for the lead paint poisoning is multiplicative rather than linear, but can be made linear by taking the logarithms of both sides of the equation. In equation 3.2

$$Y = b_0 X_1^{b_1} X_2^{b_2}.$$

Taking logarithms of both sides yields

$$\log Y = \log b_0 + b_1 \cdot \log X_1 + b_2 \cdot \log X_2.$$

Changing variables for clarity: letting $b' = \log b_0$, $Y' = \log Y$, $X_1' = \log X_1$, and $X_2' = \log X_2$, we have

$$Y' = b' + b_1X_1' + b_2X_2' \qquad (3.4)$$

which is a linear model form equivalent to equation 3.2.

Several criteria can be used for comparing models obtained by this procedure, but care must be taken in the analysis since the models result from a fit to a single data set and may reflect anomalies peculiar to that set. Figure 2 illustrates this situation. Curves a and b both pass through the three points P_1, P_2, and P_3 but their values at the vertical dotted line are quite different. Both curves fit the data exactly, but both will not predict equally well. Therefore judging the quality of a model requires, in addition to the mechanical criteria used in curve fitting, some determination of whether the model actually mirrors the process it is supposed to describe.

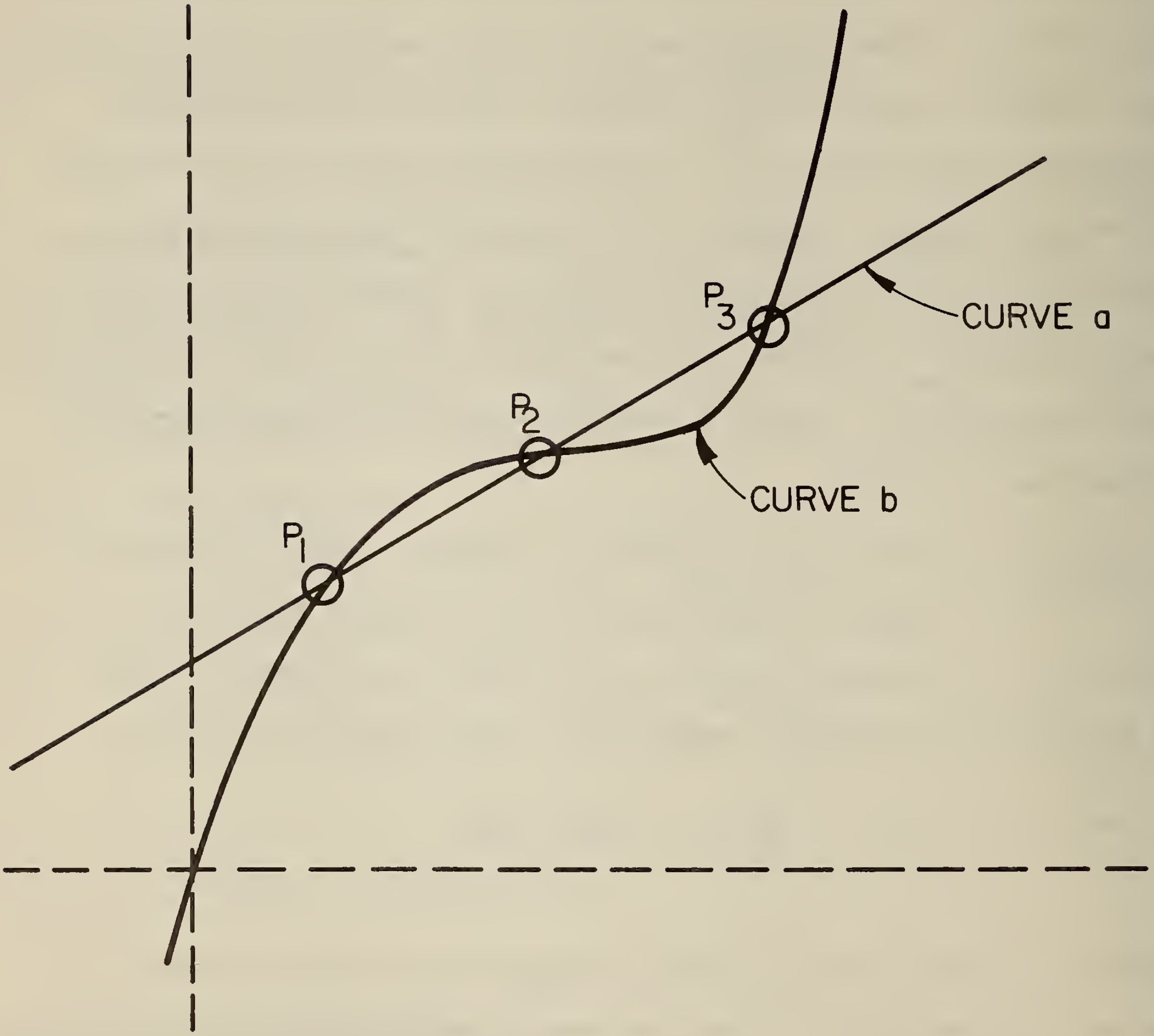
Two major criteria have been used to compare models for lead paint poisoning. The first of these involves the calculation of a statistical measure of the accuracy of the fit of the model to the data, the square of the multiple correlation coefficient, called R-square and written R^2.

$$R^2 = 1 - \frac{\Sigma(y_i - \hat{y}_i)^2}{\Sigma y_i^{\,2}}$$

where y_i are the observed values of the phenomenon and $\hat{y}_i$ are those estimated by the model. A model is deemed acceptable if 1) R^2 (for the log linear form) exceeds .9 and 2) for refinements produced by the introduction of additional variables, no attempted refinement has an R^2 which is greater than that of the original model by .05. This latter criterion sets a tradeoff between model complexity and fit-improvement.

Figure 2

Two Curves Passing Through the Same Three Points



As was stated above, no model should be judged solely on a goodness of fit criterion such as R^2, but should be evaluated also on its behavior. One relatively simple test that can be applied to the calculated parameters (coefficients and exponents) is whether their signs are consistent with our judgments (or prejudices). For example, we would expect the variable "median family income" to appear in the lead poisoning model with a negative exponent, because we believe the incidence of EBL in an area to decrease as the income level rises. If the characteristics of a parameter are "counterintuitive" then the data sample may be distorted, the variable may have been selected by erroneous reasoning, or indeed the rationale for the sign criterion may be mistaken.

3.4. The Models

The simplest multiplicative model would apply if the concurrent presence of the listed factors insured the presence of lead poisoning. One possible form for such a model for lead poisoning is that of a conditional probability model in which the expected number of children with EBL is the child population size, times the probability that a child will live in a hazardous environment, times the probability a child so situated will ingest lead. The models described below equate a hazardous environment with housing which is either dilapidated or deteriorating. Thus the models are of the form

$$E = K \cdot \frac{D}{H} \cdot I \qquad (3.3)$$

where E : the number of children with EBL

K : the number of children

D : the number of dilapidated or deteriorating housing units

H : the number of housing units

I : an EBL incidence rate for children living in a hazardous environment.

(Interpreting $\frac{D}{H}$ as the probability that a child will live in a hazardous environment involves the assumption that the number of children per household is the same for a high risk environment as for a lower risk one.)

The data base and our understanding of the lead ingestion process do not lend themselves to such an exact interpretation of I, the probability that a child living in a hazardous environment will ingest lead. Two different "models" for I have been developed separately: one has I constant and the other uses not a simple multiplicative form, but rather one in which non-unitary exponents are introduced to reflect the different levels of contributions of the factors.

3.4.1. Model 1

Model 1 is a simple model developed early in the project. It has the form

$$E = K_6 \cdot \frac{D}{H} \cdot I_0$$

where E is the predicted number of children with EBL for an appropriate population

K_6 is the number of children 6 years of age or less

D is the number of unsound housing units (dilapidated or deteriorating)

H is the total number of housing units

I_0 is a (constant) EBL incidence rate for high risk children.

I_0 was estimated as the average (.24) of the EBL rates listed in Table 15. The rate for high risk children is thus taken as constant, and the rate for the whole child population in an area depends only on the fraction of unsound housing units in that area.

3.4.2. Model 1A

Model 1A is similar to Model 1, but the constant rate I_0 is replaced by a variable rate I calculated as a function of the characteristics of the area in question:

$$I = .747 \left(\frac{K_6}{P}\right)^{.2967} \left(\frac{D}{H}\right)^{.2484}$$

where K_6, D, and H are as in Model 1 and

P is the total population.

The parameters (the numbers .747, .2967, and .2484) were estimated using the New Haven data listed in Table 9, and I was calculated as the number of children with EBL divided by the number of children screened. Only those tracts in which more than 10 children were screened were used in the calibration. The R^2 associated with this calibration is high (.945), and the signs of both exponents are as expected since incidence rises as the fraction of housing in poor condition rises or as the fraction of total population which is children 6 or under rises. Other models of this type are described in Appendix A. This model has been judged best according to the criteria given in section 3.3.

Table 15

Preliminary Data on EBL Rates

City	EBL Rate %	Source
New York 1969	45.5	Cong. Record 10/18/71; article by Guinee, submitted by Cong. Ryan
New York 1970	28.8	Lead Poisoning Control Bureau, City of New York·
Aurora, Ill.	20.8	Kane Co. Council for Economic Opportunity, G. Tollaksen
Aurora, Ill.	24.3	"Pediatric Lead Poisoning in Illinois", Phillip R. Fine and Richard H. Suhs
Springfield, Ill.	30.1	
Peoria, Ill.	31.3	
E. St. Louis, Ill.	24.7	
Decatur, Ill.	12.2	
Joliet, Ill.	24.3	
Rock Island, Ill.	21.1	
E. Moline, Ill.	11.4	
Robbins, Ill.	12.6	
Harvey, Ill.	16.4	
Carbondale, Ill.	17.0	
Norfolk, Va.	22.7	Lead Poisoning Program, Norfolk Health Dept., Ebbut
New Haven, Conn.	23.7	New Haven Lead Paint Poisoning Program, Elaine Whitmire
Baltimore 1968	25.3	"Undue Absorption of Lead Among Children - A New Look at an Old Problem", Jane Lin-Fu, PHS
Baltimore 1969	27.3	
Baltimore 1970	31.5	
Washington, D.C. 1971	19.5	D.C. Model Cities, Dudley Anderson

4. VALIDATION

4.1. Introduction

Model validation ideally refers to a process wherein the results predicted by a mathematical model in specific instances are compared with the corresponding events in the real world, in order to increase confidence in all model predictions, or alternatively, to learn that the model needs to be revised or discarded.

There are two levels of validation required. The first involves checking the assumptions upon which the model rests, those determining which factors are important and which can be omitted, as well as those determining the general mathematical form of the model. The second level of validation is the comparison of the magnitude of the phenomenon as predicted by the model and as actually occurring, to ensure that the model is a good estimator.

There are two major reasons it is necessary to validate a model.

1. Data anomalies peculiar to one region or situation may not be recognized as such and may become major determinants in the model form.
2. Model hypotheses based on the analysis of a phenomenon in one context may not carry over into others.

The only variables which emerged from the analysis of the New Haven data described in Chapter 3 as major determinants of EBL's were the relative size of the child population six years and under, and the extent of dilapidated and deteriorating housing. Thus the model was based on the hypothesis that young children living in poor housing run the greatest risk of lead poisoning. This hypothesis does not rest solely on the New Haven experience but comes also from the general findings in New York and Chicago. However the actual degree and form of the dependence, as well as the exclusion of other factors, result from the analysis of New Haven's data and must be verified elsewhere by the model validation process.

When the models were being developed, New Haven was the only source of data which had EBL's aggregated by Census tract. An additional data source became available late in 1971. In the city of Aurora, Illinois, a task force (spurred by the finding that 91 out of about 450 children tested there by the Illinois Department of Public Health exhibited EBL, and by the subsequent death of one of these children) screened over 1700 children between July and October of 1971.

The two cities, Aurora and New Haven, differ in many respects, and validation of the models with data from Aurora will thus widen the known range of the models' applicability. Aurora is in a different part of the country (the Midwest as compared with the East) from New Haven, the calibration city, and has a different character as a city. New Haven itself forms an SMSA, but Aurora is part of the larger Chicago SMSA and is partly a suburban bedroom community. The center of Aurora is an old city originally built along the Fox River and the Burlington Railroad yards, at a distance of about 35 miles from the center of Chicago. At present, Aurora is included among the expanding suburbs of Chicago, and its small town character has changed much in recent years.

Verification of the models' estimates of EBL frequency for Aurora will not, of course, assure the accuracy of the models' other estimates.

In fact, although good agreement with actual Aurora findings will encourage acceptance of the models' estimates for small and medium size cities elsewhere in the East and Midwest, we will still lack verification of the estimates for other areas of the country, such as the South, the Mountain States, and the West Coast. These areas have quite different climatic characteristics, possibly different techniques of home construction and decoration, and different proportions of older housing. Data on EBL from some cities in these areas are needed to really establish the validity of the estimates there. In the current absence of such data, validation using Aurora data can at least improve our confidence in the general assumptions upon which the models were built, and in particular can alleviate the risk that the models reflect unduly the specific character of New Haven.

4.2. Validation of Model Assumptions - Analysis of the Aurora Data

4.2.1. General Description of the Aurora Data

In July of 1971 the Illinois Department of Public Health tested 449 children in Aurora, Illinois. Of these, 91 were found to have EBL's, five with high enough levels to warrant hospitalization. This testing in Aurora was part of a 10 city survey conducted by the Department to ascertain why, of the total of over 2000 lead poisoning cases reported to them each year, only a handful occurred outside the City of Chicago, although less than half of the children in the applicable age range live in Chicago, and housing conditions similar to those in Chicago's poorer areas are also found in other cities in the state. The Aurora tests and those in other Illinois cities revealed that the disease is widespread outside Chicago but had remained largely unrecognized. This is an excellent example of the circumstance mentioned previously, that the number of children found with EBL's depends directly on the effort spent in searching.

Once the presence of lead poisoning in Aurora became known, a program directed by the Aurora Service Center of the Kane County Council of Economic Opportunity (staffed almost wholly by volunteers) was launched to test the remainder of those children in Aurora living in neighborhoods containing poor housing. In 1971, 1707 children, 12.8% of all children 6 years of age or less in Aurora, were tested. (This figure includes the 449 originally tested by the Illinois Department of Public Health, but does not include 86 ostensibly non-high risk "middle class" children tested for statistical control purposes.) 321 of these, or 18.8 percent, had EBL's. Table 16 gives, for each census tract in Aurora, the total number of children 6 years and under (from the 1970 Census), the number of children screened, the percent of children screened, the number of those children screened found with EBL's, and the percentage of those screened with EBL. The extent of the screening coverage can be measured by the fact that in only one of Aurora's 16 census tracts were less than 5 percent of the children screened, while in four tracts more than 20 percent were screened.

Aurora officials have estimated that all high risk children have been screened in this program. Their estimate of 1700 children in high risk neighborhoods is quite naturally greater than the NBS estimate of

Table 16

Aurora Screening Statistics by Census Tract

CENSUS TRACT	TOTAL CHILDREN	CHILDREN SCREENED	PERCENT SCREENED	TOTAL EBL	PERCENT EBL
8529	2116.	173.	8.2	25.	14.5
8530	2109.	73.	3.5	9.	12.3
8531	391.	20.	5.1	5.	25.0
8532	944.	100.	10.6	28.	28.0
8533	380.	49.	12.9	6.	12.2
8534	1122.	283.	25.2	64.	22.6
8535	556.	96.	17.3	11.	11.5
8536	772.	225.	29.1	48.	21.3
8537	30.	5.	16.7	1.	20.0
8538	386.	49.	12.7	11.	22.4
8539	826.	41.	5.0	7.	17.1
8540	1099.	240.	21.8	50.	20.8
8541	517.	82.	15.9	19.	23.2
8542	527.	58.	11.0	7.	12.1
8543	827.	42.	5.1	3.	7.1
8544	788.	172.	21.8	27.	15.7
Total	13390.	1708.	12.8	321.	18.8

Values in the tables in this section are computer output and subject to round-off error. For this reason totals from different tables may not agree and percentages may not total 100.

over 1300 in high risk housing units, since some of the housing in a high risk neighborhood may be in good condition. It is clear that any program intending to test all high risk children will have to screen more than the bare minimum of children, since it is impossible to draw neighborhood boundaries strictly enough to include only children living in poor housing. Also, programs run by government affiliated groups must accept all children whose parents request a test. In addition, health officials see great benefit in testing any child, regardless of socio-economic status, who might have been exposed to the lead hazard. The problem for most programs is not that of having to turn away children desiring the test, but that of persuading parents of exposed children to allow the test to be done. The Aurora program which tested over 12 percent of all children has succeeded well in this respect and it is very probable that most, if not quite all, of the high risk children have been tested.

4.2.2. Factors Associated with EBL

The Aurora officials allowed NBS staff access to the forms which were filled out for each child. These forms had information concerning the child and his family in addition to the blood lead level. This information was coded and punched at NBS on computer cards for an analysis of characteristics actually associated with children with EBL. The forms contained only the street address for each child's home, but the correct census tract was coded for each address by hand using a street directory and street maps of the Aurora area. A small number (fewer than 10 forms) could not be coded because the street could not be found in the directory or on the maps, the street was found in a tract not included in our study, or only a Post Office box number was given as an address.

Table 17 lists the data items coded from the Aurora forms. Not all forms contained all twelve items, of course. Some items were not filled in on some forms, and these items were coded as blanks, unless other information, such as a form for another child in the same family (which could be used for all but items 1, 3, 4 and 12) or the child's name (which could be used to determine the child's sex), was available to fill in the blank. Three different forms had been used for the three different test dates on which the survey was run: the first contained only items 1 through 6, the second contained all items except 11; and the third contained all 12 items. The use of these different forms thus accounts for many of the blanks observed in the data. Table 18 records the number of blanks found for each of items 2 through 12. There are no blanks for blood lead level, since any form lacking this information was discarded. Only 19 retests were included in this study, and therefore any conclusions about them are based on a very small sample.

Table 19 displays the distribution of blood lead levels for the Aurora children, separately for first time tests and for retests. As just noted, the number of retests is too small to make possible sound generalizations concerning EBL rates for children in programs with periodic retesting. The fact that only those children whose initial tests were high were retested may explain why the distribution of retest blood lead levels

Table 17

Data Items Coded From the Aurora Forms

1. blood lead level
2. census tract
3. sex of child
4. age of child
5. race or ethnic origin
6. whether or not the child has a family doctor
7. time of residence at the present address
8. whether the family owns or rents its home
9. whether or not the family receives public aid
10. a family number to identify children in the same family
11. condition of the house the child lives in
12. retest blood lead level, if child was retested.

Table 18

Aurora, Illinois Data Statistics

There are	3	blanks in the column for	(2) tract
	0		(3) sex
	17		(4) age
	22		(5) race
	20		(6) doctor
	331		(7) transiency
	363		(8) tenure
	352		(9) aid
	1361		(11) condition

There is a total of 1726 tests of which 19 are retests. The total number of families is 1044. The numbers in parentheses are the indices used in Table 17.

Table 19

Blood Lead Levels (µg/100 ml) for Aurora, Ill. Children

Blood Lead Level	Number of Initial Tests
0 - 9	246.
10 - 19	389.
20 - 29	461.
30 - 39	293.
40 - 49	178.
50 - 59	71.
60 - 69	29.
70 - 79	17.
80 - 89	12.
90 - 99	6.
100 and Up	8.

Blood Lead Level	% Initial Tests
0 - 9	14.3
10 - 19	22.5
20 - 29	26.7
30 - 39	17.0
40 - 49	10.3
50 - 59	4.1
60 - 69	1.7
70 - 79	1.0
80 - 89	.7
90 - 99	.3
100 and Up	.5

Blood Lead Level	Number of Retests
0 - 9	0.
10 - 19	3.
20 - 29	1.
30 - 39	5.
40 - 49	6.
50 - 59	4.
60 - 69	0.
70 - 79	0.
80 - 89	0.
90 - 99	0.
100 and Up	0.

Blood Lead Level	% Retests
0 - 9	.0
10 - 19	15.8
20 - 29	5.3
30 - 39	26.3
40 - 49	31.6
50 - 59	21.1
60 - 69	.0
70 - 79	.0
80 - 89	.0
90 - 99	.0
100 and Up	.0

has a higher mean than that for first time tests. Table 19 contains not only (on the right) the percentage distribution of blood lead levels, but also (on the left) the actual numbers found in each category. While percentages do not seem to have a great impact on our emotions, the observation that 26 children tested in Aurora had blood lead levels greater than 80 μg/100 ml, which the Surgeon General recommends as the level at which the child be considered lead poisoned and possibly suffering irreparable brain damage, conveys the enormity of the problem more graphically. One of these children has died. We should remember that Aurora is only a small city, and that there are many others like it with no programs to screen for or treat lead poisoning. In addition to the 26 children with defined lead poisoning cases, some of the 46 children with levels between 60 μg/100 ml and 80 μg/100 ml may be exhibiting other symptoms[28] and may have suffered brain damage.

Table 20 gives a breakdown of the children with EBL by first time tested versus retests. Again, both the absolute numbers as well as the percentages are recorded, as they will be in succeeding tables. Only 1.1 percent of all tests were retests, and only children whose first test indicated an EBL were retested. Almost half of the children's blood levels were below 40 μg/100 ml on retest. Whether this is because of treatment, inexactitude in one of the tests, or increased surveillance by a parent is not known. It means however, that slightly more than half have levels still above 40 μg/100 ml and thus remain in danger. This agrees with findings in other cities that indicate high incidence of recurrence of EBL if the child is returned to a contaminated environment. Aurora authorities ran their

Table 20

Breakdowns of EBL's by Tests and Retests

Testing	Number Under 40	Number 40 and Above	Total
First Time	1390.	318.	1708.
Retests	9.	10.	19.

Testing	% Under 40	% 40 and Above	Total
First Time	81.4	18.6	98.9
Retests	47.4	52.6	1.1

The percentages in the right hand column refer to the percent of all children tested falling into each of the categories "First Time" and "Retests".

screening program virtually on a shoestring, and were thus able to do no more about the environment in which the children lived than to warn parents of the danger. Only one house, that of the child who died, was deleaded. It is not known if there are other cases in which a landlord or homeowner, informed of the danger by the screening program, deleaded a property on his own initiative.

Table 21 lists the number of EBL's found in each census tract. Figure 3 is a map of Aurora showing the geographic locations of all sixteen of these Census tracts, with those having high EBL rates filled in with diagonal lines. As can be seen from the table, the percentage of children with EBL varies from a low of 8.1 in tract 8543 to a high of 28 in tract 8532. However, the tract with the lowest absolute number of children with EBL is 8537, a downtown area with few residences. The highest number of EBL's (64) is found in 8534. Other tracts with many EBL's are 8540 with 50 and 8536 with 48.

Table 22 gives the breakdown of EBL's by sex of child. The Aurora screening program tested girls and boys in almost equal numbers and the fractions of those tested having EBL are almost the same. From this table one can conclude that lead poisoning is a disease afflicting both males and females, with very little difference in the incidence rates for the two, a fact which agrees with findings elsewhere.

Table 23 gives the breakdown of EBL's by age of the child. Aurora screened approximately equal numbers of children in each of the yearly age ranges 1 to 6. (Only about 4 percent of the children screened were 7 or 8.)

Table 21

Breakdowns of EBL's by Census Tract

Tract	Number Under 40	Number 40 and Above	Total
8529	148.	25.	173.
8530	64.	9.	73.
8531	15.	5.	20.
8532	72.	28.	100.
8533	43.	6.	49.
8534	219.	64.	283.
8535	85.	11.	96.
8536	177.	48.	225.
8537	4.	1.	5.
8538	38.	11.	49.
8539	34.	7.	41.
8540	190.	50.	240.
8541	63.	19.	82.
8542	51.	7.	58.
8543	39.	3.	42.
8544	145.	27.	172.
Total	1387.	321.	1708.

Tract	% Under 40	% 40 and Above	Total
8529	85.5	14.5	10.1
8530	87.7	12.3	4.3
8531	75.0	25.0	1.2
8532	72.0	28.0	5.9
8533	87.8	12.2	2.9
8534	77.4	22.6	16.6
8535	88.5	11.5	5.6
8536	78.7	21.3	13.2
8537	80.0	20.0	.3
8538	77.6	22.4	2.9
8539	82.9	17.1	2.4
8540	79.2	20.8	14.1
8541	76.8	23.2	4.8
8542	87.9	12.1	3.4
8543	92.9	7.1	2.5
8544	84.3	15.7	10.1
Total	81.2	18.8	

Figure 3

Map of Aurora Census Tracts Having High EBL Rates

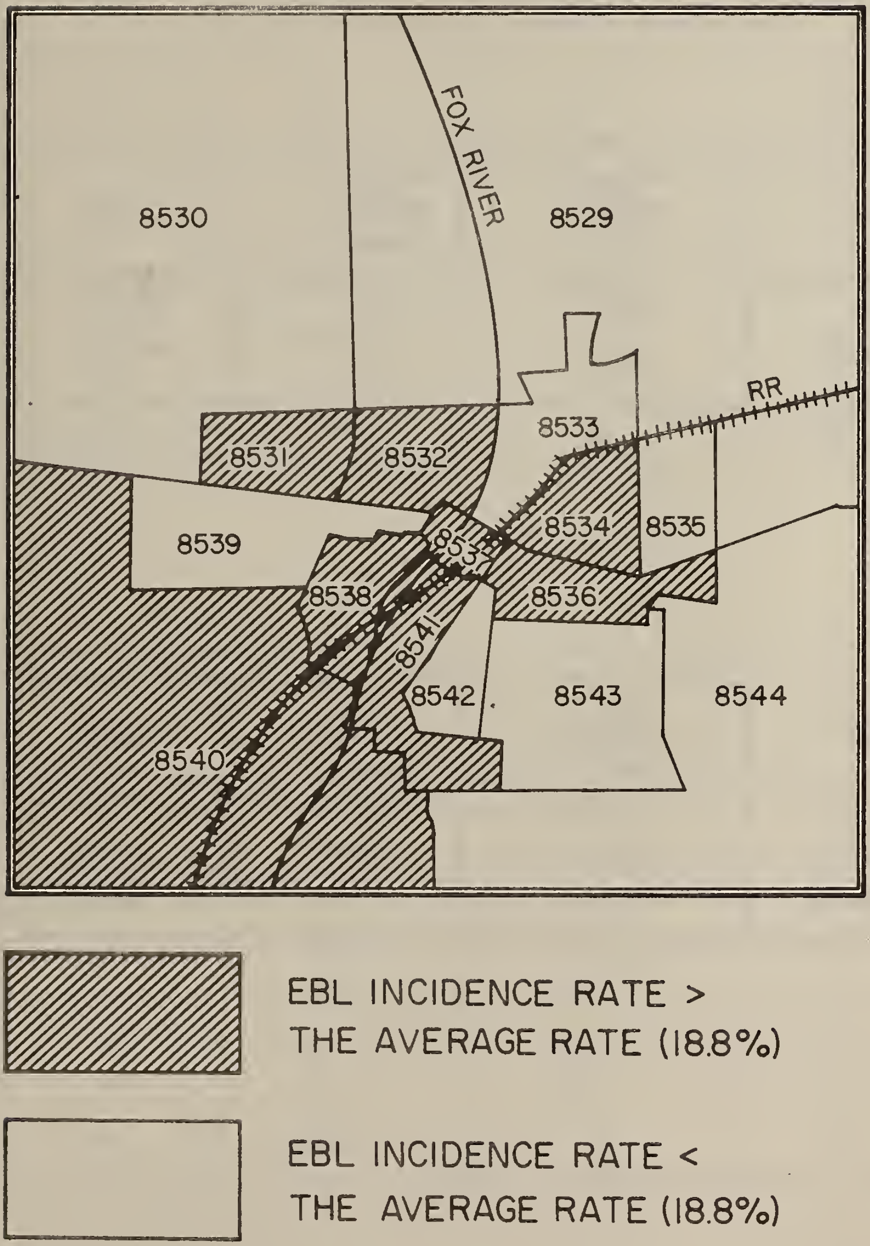


Table 22

Breakdowns of EBL's by Sex of Child

Sex	Number Under 40	Number 40 and Above	Total
Male	706.	176.	882.
Female	683.	145.	828.

Sex	% Under 40	% 40 and Above	Total
Male	80.0	20.0	51.6
Female	82.5	17.5	48.4

Table 23

Breakdowns of EBL's by Age of Child

Age	Number Under 40	Number 40 and Above	Total
1	192.	40.	232.
2	231.	69.	300.
3	243.	60.	303.
4	212.	51.	263.
5	239.	50.	289.
6	202.	39.	241.
7	50.	9.	59.
8	5.	0.	5.

Age	% Under 40	% 40 and Above	Total
1	82.8	17.2	13.7
2	77.0	23.0	17.7
3	80.2	19.8	17.9
4	80.6	19.4	15.5
5	82.7	17.3	17.1
6	83.8	16.2	14.2
7	84.7	15.3	3.5
8	100.0	.0	.3

The EBL rates for each of the ages 1 to 6 are approximately the same, with only a slightly higher rate for 2 year olds. This differs from results reported by other programs, which found relatively many more children in the 2 to 3 year old range to have EBL's. The reason for the discrepancy is not known.

Table 24 gives the breakdowns of EBL's by race or ethnic origin of the child. Black children have the highest rate, 24.2 percent. Spanish surnamed children have the intermediate rate of 20.6 percent. White children are lowest with 14.2 percent. The Aurora sample contained a larger proportion of black and Spanish surnamed children than would be found in the population as a whole. This is undoubtedly because the program sought to test all high risk children (i.e., those living in poor quality housing), and it is known that these minority groups make up a disproportionate fraction of the lower income groups living in such housing.

Table 25 gives the breakdowns of EBL's by whether or not the child has a family doctor. This table is included to test the hypothesis that a child who has regular contact with the medical establishment has less chance to have an EBL. As can be seen clearly, however, this is not true in Aurora. The EBL rates are almost identical whether or not the child has a family doctor. The most surprising statistic to emerge from this table is that over 90 percent of the children were reported as having a family doctor. The actual figure may not in fact be quite so high. In at least two cases the mother noted on the form that the doctor listed was "mother's baby doctor". Also, since treatment of EBL's was done by local physicians, we believe that mothers were urged to write down the name of the doctor they would take their child to if he had an EBL.

Table 24

Breakdowns of EBL's by Race or Ethnic Origin

Race	Number Under 40	Number 40 and Under	Total
White	647.	107.	754.
Black	338.	108.	446.
Spanish	389.	101.	490.

Race	% Under 40	% 40 and Above	Total
White	85.8	14.2	44.6
Black	75.8	24.2	26.4
Spanish	79.4	20.6	29.0

Table 25

Breakdowns of EBL's by Whether or Not the Child Has a Family Doctor

Doctor	Number Under 40	Number 40 and Above	Total
Yes	1242.	289.	1531.
No	130.	29.	159.

Doctor	% Under 40	% 40 and Above	Total
Yes	81.1	18.9	90.6
No	81.8	18.2	9.4

The 90 percent figure is suspiciously high, but even a figure of 70 or 80 percent would indicate a greater contact of these small city families with the regular medical profession than that of large city poor families. Increasing the doctors' awareness of the danger posed by lead paint and of the symptoms of lead poisoning may by itself provide a great payoff in lead poisoning control.

Table 26 gives the breakdown of EBL's by duration of the family's residence at its present address. It has been speculated that poorer families are more transient. Therefore it was hoped that transiency rates could be used to distinguish those with high EBL rates. However Table 26 shows that there is not a great deal of difference in EBL rate among the various lengths of residence, and the differences which exist do not form the pattern expected under the above hypothesis. Why the highest rate, 27.1 percent, should be for those who have lived at their present address for four years is not at all clear, when the corresponding rate for three years is 20.8 percent and for 5 years is 19.0. The low rate of 16.5 for those living at the same address 5 or more years is in the direction expected, but is not different enough to be statistically significant. The figures in Table 26 may just reflect the fact that frequent changes of residence are characteristic of life today. One demurrer must be placed on these statistics, however. Many of the forms only recorded the address of the family back to the child's birth (only up to 3 years ago, for instance, for a 3 year old child) and left the other spaces blank. If the address was the same as the present address, the family was usually

Table 26

Breakdowns of EBL's by Time of Residence at the Present Address

Time of Residence at this Address	Number Under 40	Number 40 and Above	Total
Less than 1 month	47.	12.	59.
Less than 6 months	161.	50.	211.
Less than 1 year	137.	36.	173.
Less than 2 years	143.	45.	188.
Less than 3 years	99.	26.	125.
Less than 4 years	70.	26.	96.
Less than 5 years	34.	8.	42.
At least 5 years	405.	80.	485.

Time of Residence at this Address	% Under 40	% 40 and Above	Total
Less than 1 month	79.7	20.3	4.3
Less than 6 months	76.3	23.7	15.3
Less than 1 year	79.2	20.8	12.5
Less than 2 years	76.1	23.9	13.6
Less than 3 years	79.2	20.8	9.1
Less than 4 years	72.9	27.1	7.0
Less than 5 years	81.0	19.0	3.0
At least 5 years	83.5	16.5	35.2

coded as having lived there at least 5 years since there was no other address listed. This practice may have led to the high percentage of those tested recorded as living at their present address "at least 5 years", and low percentages for less than 4 or 5 years.

Table 27 gives the breakdown of EBL's by whether the family owns or rents its home. In the larger cities a high percentage of the population at all income levels rents housing. In a smaller city one would expect that a smaller percentage rents, and that the poor are more likely to rent than those more affluent. Thus lead poisoning may be higher among renters. The Aurora sample of high risk children is divided almost evenly among renters and owners. The EBL rates are almost the same for the two categories, and thus it is not the case that children of renters show a higher probability of contracting EBL.

Table 28 gives the breakdown of EBL's by whether or not the family receives some form of public aid. The most common kinds of aid listed were food stamps and ADC (Aid to Dependent Children), commonly called welfare. This was the only item on the forms which was specifically related to income, since a family must be in the lowest income bracket to receive public aid. As expected, those on an aid program had a much higher probability of having an EBL than those not on aid. A more detailed breakdown of income and EBL would have been desirable, but it is clear from Table 28 that those below the poverty level have higher EBL rates than even other high risk children. This may be modified somewhat in Aurora in the future since a new public housing project, presumably not containing lead paint,

Table 27

Breakdowns of EBL's by Whether the Family Owns or Rents Its Home

Tenancy	Number Under 40	Number 40 and Above	Total
Own	530.	124.	654.
Rent	542.	151.	693.

Tenancy	% Under 40	% 40 and Above	Total
Own	81.0	19.0	48.6
Rent	78.2	21.8	51.4

Table 28

Breakdowns of EBL's by Whether or Not the Family Receives Public Aid

Public Aid	Number Under 40	Number 40 and Above	Total
On Aid	142.	53.	195.
Not	939.	224.	1163.

Public Aid	% Under 40	% 40 and Above	Total
On Aid	72.8	27.2	14.4
Not	80.7	19.3	85.6

has recently been opened. However, until the units formerly occupied by these new public housing residents are deleaded, the hazard will still exist for whoever will live in those units.

Table 29 gives a breakdown of EBL's by the condition of the house occupied by the child. The conditions listed are "(1) very poor, paint is chipped and peeling on doors, windowsills, and/or on the outside of the house, (2) not too bad, some peeling, could easily be improved, and (3) good, walls are firm; no chipping or peeling on outside or inside of house". The responses are of course subjective assessments by the residents of their own housing. What one family might term as good, because it was much better than their previous housing, another might think is only fair. A homeowner might believe some item could be easily repaired and therefore term his house in fair condition, while a renter, who has to rely on someone else to fix the item, might feel it was more difficult to repair and thus term the same home in poor condition. However, even taking into account the subjectivity of this categorization, there is a great difference (a factor of 2) in the EBL rates for housing termed good versus that termed fair or poor. This is certainly a corroboration of the basic premise of the model, that children living in housing in poor condition suffer a higher risk of EBL.

The dependence of EBL incidence on housing condition also increases confidence in the assumption on which all our work has been based, that the primary cause of pediatric lead poisoning is the ingestion of leaded paints, since the total body burden of lead (as measured by that in the

Table 29

Breakdowns of EBL's by the Condition of the Housing Unit Occupied by the Family

Housing Condition	Number Under 40	Number 40 and Above	Total
Poor	9.	2.	11.
Fair	90.	24.	114.
Good	204.	24.	228.

Housing Condition	% Under 40	% 40 and Above	Total
Poor	81.8	18.2	3.1
Fair	78.9	21.1	32.3
Good	89.5	10.5	64.6

blood) is associated with the condition of the unit in which the child resides.

Table 30 gives a breakdown by family size of the number of children in the same family with EBL's. This table shows that as the number of children in a family goes up, the probability that at least one child in the family will have an EBL also rises (except for a slight decrease in 5 children families), which would be expected even if EBL's do not tend to run in families. If the tendency of EBL to run in families were perfect, i.e., if all children in a family had EBL whenever any one of them did, the table would be as follows.

	0	1	2	3	4
1	471	109	-	-	-
2	245	0	57	-	-
3	99	0	0	23	-
4	25	0	0	0	6

(We have omitted 5 children families because there are too few of them to generalize from.) This is not the case in Table 30, since non-zero entries occur. At the opposite extreme, if there were no such tendency at all and the probability that a child had an EBL were the average .188 observed for all children, the numbers occurring in Table 30 (omitting 5 children families as above) would be as follows (on page 94).

Table 30

Number of Families of Each Family Size Having a Given Number of Children with Elevated Blood Lead Levels

Family Size (Children 7 and Under)	Number of Children in the Same Family With Elevated Blood Lead Levels						
	0	1	2	3	4	5	All
1	471.	109.	-	-	-	-	580.
2	196.	91.	15.	-	-	-	302.
3	72.	36.	11.	3.	-	-	122.
4	17.	10.	4.	0.	0.	-	31.
5	4.	1.	2.	0.	0.	0.	7.

Percent of Families of Each Family Size Having a Given Number of Children with Elevated Blood Lead Levels

Family Size (Children 7 and Under)	Number of Children in the Same Family With Elevated Blood Lead Levels						
	0	1	2	3	4	5	All
1	81.2	18.8	-	-	-	-	55.7
2	64.9	30.1	5.0	-	-	-	29.0
3	59.0	29.5	9.0	2.5	-	-	11.7
4	54.8	32.3	12.9	.0	.0	-	3.0
5	57.1	14.3	28.6	.0	.0	.0	.7

	0	1	2	3	4	All
1	471	109	-	-	-	580
2	199	92	11	-	-	302
3	65	45	11	1	-	122
4	13	13	4	1	0	31

The differences between those observed in Table 30 and those expected under the assumption that EBL's do not run in families are displayed below. These differences are all quite small.

	0	1	2	3	4
1	0	0	-	-	-
2	-3	-1	4	-	-
3	7	-9	0	2	-
4	4	-3	0	-1	0

A Chi-square test[29] was performed separately on each of rows 1, 2, and 3 (the last two entries in row 4 of Table 30 are too small for the test to be applicable there) to test if, for families of a fixed size, the tendency toward EBL runs in the family. This was strongly not the case for each of the family sizes 1 child, 2 children, and 3 children 7 years or younger.

The fact that EBL's do not run in families means that testing and deleading programs cannot take advantage of the spatial concentration of children in families. If EBL's ran in families, one could screen families by testing only one child in the family. Furthermore, for a given EBL rate, fewer units would require deleading. But since the probability that a child has an EBL does not depend significantly on whether others in his family have EBL's, screening programs must screen as many children as possible, regardless of the number of families they represent. The number of units to be deleaded is approximately the number of EBL's found divided by the average number of children in the same family in the applicable age range.

Chi square tests, designed to reveal which factors are statistically associated with EBL, were run on the 10 factors shown in Tables 20 through 29 and discussed above. Table 31 summarizes the results of these tests. The significant difference for retests stems from the fact, noted in the discussion of Table 20, that children were retested only if they had an EBL the first time. Thus without a deleading of the child's environment one would expect retests to have higher blood lead levels than the ordinary population. The significant difference for the "census tract" factor reassures us that the modeling effort is indeed feasible, for if blood lead levels did not differ from one tract to the next, one could never hope to calibrate a model, i.e., one cannot model differences in EBL rates among census tracts if such differences do not exist.

The other three items which turn out to be statistically significant also reinforce our confidence in the model which has been developed. Housing condition has proved to be significant, and being a member of a minority group or on public aid are closely associated with income level,

Table 31

Results of Chi Square Tests

Item	Chi Square	Degrees of Freedom	Significance Level*
Retest	14.12	1	.01
Census Tract	27.35	15	.05
Sex	1.67	1	-
Age	7.25	7	-
Race	20.19	2	.01
Doctor	.04	1	-
Transiency	10.08	7	-
Tenure	1.66	1	-
Public Aid	6.45	1	.05
Housing	7.08	2	.05

---

*The observed value of Chi-square will be exceeded with probability less than the significance level indicated if in fact there is no difference for the factor considered.

which determines who lives in housing in poor condition. Such factors as the age of the child (note that all children tested were under 8 and most were 6 and under, so we are not referring to older children), the child's sex, whether the child has a family doctor, how long the family has resided at its present address, or whether the family owns or rents its home are not statistically significant, although at first thought most of these would be suspected to have some influence on EBL. The emphasis on poor housing to the exclusion of other factors, discovered in the course of the calibration on New Haven data, is confirmed by the data from Aurora. The Aurora data are particularly useful for this kind of test, since one could associate the particular characteristics of one child with his blood lead level.

The analysis of the Aurora data generally supports the assumptions built into the lead poisoning model developed by NBS. This analysis has also increased our knowledge of factors associated with EBL, even if only by ruling out some plausible associates. Such negative results help us focus on the major factors: poor housing condition and low income.

4.3. Validation of Quantitative Model Performance

A second part of the validation process will be reported in this section: the checking of model-predicted EBL frequencies against those discovered in the Aurora screening program. Table 32 gives the number of EBL's found in the Aurora screening effort and those predicted by each of the two models, Model 1 and Model 1A, described in Chapter 3. As can be seen from a glance at this table, there is substantial agreement between

Table 32

EBL's by Census Tract from the Aurora Data and as Predicted by Model 1 and Model 1A

Census Tract	Aurora Screening	Model 1 Predicted EBL	Model 1A Predicted EBL
8529	25	30	26
8530	9	30	27
8531	5	6	5
8532	28	15	14
8533	6	5	4
8534	64	48	57
8535	11	24	27
8536	48	42	51
8537	1	1	1
8538	11	16	19
8539	7	10	8
8540	50	31	31
8541	19	23	26
8542	7	7	6
8543	3	9	7
8544	27	22	22
Total	321	319	331

the predictions of the two models for each census tract. In addition, the "highs" and "lows" of the model predictions agree quite well with those of the EBL's actually found in the program. To confirm this, a statistical test associated with Kendall's rank correlation coefficient tau[30] was performed, leading to a 99 percent confidence level for the agreement between the predictions of Model 1 and also of Model 1A with the Aurora data. Since this statistical test only compares the rank orders within the two columns, one might still question the agreement, were it not for the fact that there is only about 3 percent difference in the total predicted by Model 1A and that actually found, and Model 1 differs by less than 1 percent. The degree of agreement between predicted EBL's and those actually found is in our opinion astonishing, in view of the many problems known to exist with the data.

Table 33 gives the percentage of high risk children predicted by Model 1A to have EBL, and the percentage of the screened children with EBL. These two columns of numbers are not at all in the same kind of agreement as those in Table 32. Even the overall percentages differ by 5 percentage points. Thus in spite of the fact that the number of children found with EBL agrees with the number predicted by either Model 1 or Model 1A, the fractions of high risk children with EBL as calculated by those models do not agree with the fractions observed in children screened. An explanation for the fact that the number of EBL's are in agreement but the percentages of high risk children predicted and observed do not agree, lies in the equating of high risk children with those screened. Table 34 gives the number of children screened in each census tract and the number

Table 33

Comparison of Percent of High Risk Children Found with EBL with Those Predicted by Model 1A

Census Tract	% EBL as Found	% EBL as Predicted By Model 1A
8529	14.4	20.7
8530	12.3	22.0
8531	25.0	19.9
8532	28.0	21.9
8533	12.2	18.9
8534	22.6	28.8
8535	11.4	27.4
8536	21.1	29.5
8537	20.0	23.4
8538	22.2	28.0
8539	17.0	18.3
8540	20.8	24.1
8541	23.1	26.6
8542	12.0	19.4
8543	7.1	18.3
8544	15.7	24.6
Total	18.8	24.9

Table 34

Children Tested in the Aurora Screening Program
Versus Children at Risk as Calculated by the Models

Census Tract	Children Tested	Children At Risk	Difference (Tested-Predicted)
8529	173	124	49
8530	73	124	- 51
8531	20	27	- 7
8532	100	64	36
8533	49	20	19
8534	283	199	84
8535	96	98	- 2
8536	227	174	53
8537	5	6	- 1
8538	49	69	- 20
8539	41	42	- 1
8540	240	127	113
8541	82	96	- 14
8542	58	26	32
8543	42	39	3
8544	172	91	81
Total	1710	1326	470 - 96 = 374

of high risk children as predicted by the models. The model regards high risk children as those living in unsound (i.e., dilapidated or deteriorating) housing and calculates the number of them as

$$K_6 \times \frac{D}{H} ,$$

where K_6 is the number of children six years old or less,

D is the number of unsound housing units, and

H is the total number of housing units.

The Aurora screening program defined high risk children as those living in poor neighborhoods which contain poor housing. As discussed in section 4.2.1, it is impossible for a program such as that in Aurora to draw boundaries to specify exactly which children will be tested. Survey workers cannot agree to test one child because he lives in poor housing and refuse to test a neighbor because his house is in better condition. They can choose a blood sampling site to maximize their chances of at least testing all children living in housing presenting a lead hazard, but then must test all children who ask to be tested. They can also concentrate announcements of the test in areas of greatest risk. Table 34 shows that 374 more children were tested than were predicted to be high risk by the models. If these are actually children living in good housing and thus less likely to have EBL's, this would explain the lower rates observed.

4.4. Conclusion

The full validity of the models is not proved by the analysis of the data from Aurora. As noted in section 4.1, this would not have been possible to achieve anyway, since we still do not have information concerning EBL rates in such areas of the United States as the South and West.

The analysis of the Aurora data has, however, enhanced the believability of the models in two ways. Analysis of various factors which could be associated with lead poisoning shows that the major factor is poor housing. This was the main assumption upon which the models were built, and the analysis has corroborated that assumption. The second finding which supports the acceptability of the models is the remarkable agreement between the number of EBL's predicted and those actually found. This indicates that at least for Aurora the models could only be underpredicting the number of children with EBL, since the number predicted has already been found and only 12 percent of all children have been tested. The models included rates only for high risk children since little information is yet available on other groups. Such data are now obviously needed to obtain better estimates of the magnitude of the problem in all segments of the population. In addition to the agreement between the total EBL's predicted and found, there was surprising agreement between the two for each census tract.

Thus, although the results of this validation exercise do not conclusively prove the validity of Model 1 and Model 1A, they have increased our confidence both in the order of magnitude of the estimates and in their relative sizes for different SMSA's. Further information, including data from screening in the South and West, data to determine an accurate description of the children at risk, and data on non-high risk EBL's, is needed to be able more fully to assure the validity of the models.

5. NATIONAL ESTIMATES BY SMSA

This chapter is devoted to the presentation of the model outputs. Care should be taken in interpreting these outputs, in light of the modeling problems described in Chapter 3 and the incompleteness of validation to date as described in Chapter 4. In particular, estimates for SMSA's in the South and West are based on a model which has not been validated for those areas. It is believed by many experts[31] that lead poisoning incidence is lower in these regions than in the East and Midwest, so that the estimates given in this report (and based on data from only the East and Midwest) may be too high for SMSA's in the South and West.

The estimates given below only apply to SMSA's (which are large and medium metropolitan areas) representing approximately 68% of the total population and housing in the United States. Our cautious disclaimers notwithstanding, there is some evidence to suggest that the incidence of EBL in small cities, which are not large enough to quality as SMSA's, is similar to or only slightly lower than that of the larger metropolitan areas with similar housing characteristics. At present there is no information available concerning EBL rates for children living in rural areas. At least one study[32] has reported lower average blood lead levels for rural children, which (if the standard deviation for the distribution of rural blood lead levels is similar to that for urban ones) would lead one to expect a lower EBL rate for rural children. Thus the total EBL's as summed over all SMSA's will be less than the nationwide incidence by an unknown amount. However, if one takes into account the probable overestimation of model-calculated EBL's in the Southern and Western SMSA's noted above, the SMSA totaled EBL's (about 600,000) may be a fairly good national estimate of the number of children aged 1 to 6 who currently have EBL's. This estimate does not include either those who have had an EBL and are suffering the effects (but do not now have EBL) or those who will (without remedial action) first develop EBL's in the future.

Table 35 lists for each SMSA the number of children 6 years of age and under (according to the 1970 Census), the estimated number of high risk children (those living in dilapidated or deteriorating housing) and the number of EBL's estimated by the models 1 and 1A described in Chapter 3. These numbers have all been rounded to the nearest hundred to indicate that the model estimations are only approximate. At the end of the table, totals over 241[33] SMSA's are listed, showing about 17 million children 6 years of age or less, an estimated 2 and a half million high risk children among them, and about 600,000 EBL's to be expected in these SMSA's. Figure 4 shows the 25 SMSA's (also listed in Table 36) which have the greatest predicted incidence of EBL according to model 1. Table 36 also lists the population rank (with number 1 being the largest) or each of the 25 SMSA's, to emphasize the fact that the rank of a city as determined by the estimated number of EBL's is due in large part to its population rank. Only 4 of the top 25 SMSA's in EBL are not in the top 25 SMSA's in population.

Table 37 gives estimates of the number of children, in each SMSA, with blood lead levels of 40 μg/100 ml or more, 50 or more, 60 or more, and 70 or more. These estimates were calculated using Model 1, from Chapter 3, with the values of I_0 obtained as the observed fractions of children screened falling into these categories in the 1970 New York screening program. The relevant percentages aggregated from Table 4 in Chapter 2 are 28.9% for 40 and above, 12.7% for 50 and above, 6% for 60

Table 35

EBL's Predicted by the Models for Each SMSA

SMSA NAME	Children 6 and Under	Children At Risk	Model 1 EBL	Model 1A EBL
Abilene, Texas	13200	2800	700	700
Akron, Ohio	83700	11500	2800	2800
Albany, Georgia	13500	4400	1100	1400
Albany-Schenectady-Troy, N.Y.	86600	14100	3400	3600
Albuquerque, N.Mex.	42300	5200	1300	1300
Allentown-Bethlehem-Easton, Pa.-N.J.	59900	7200	1700	1700
Altoona, Pa.	15400	4200	1000	1200
Amarillo, Tex.	17800	2800	700	700
Anaheim-Santa Ana-Garden Grove, Cal.	184600	12600	3000	2700
Anderson, Ind.	18100	4200	1000	200
Ann Arbor, Mich.	27700	3600	900	900
Appleton-Oshkosh, Wisc.	37200	5800	1400	1500
Asheville, N.C.	16800	4600	1100	1300
Atlanta, Ga.	185300	33700	8100	9100
Atlantic City, N.J.	19500	2500	600	600
Augusta, Ga.	31800	8600	2100	2500
Austin, Tex.	35400	6700	1600	1800
Bakersfield, Cal.	42300	9100	2200	2500
Baltimore, Md.	255600	32600	7800	7900
Baton Rouge, La.	38400	7800	1900	2100
Bay City, Mich.	16300	3000	700	800
Beaumont-Port Arthur-Orange, Tex.	38300	8500	2000	2300
Billings, Mont.	10400	2500	600	700
Biloxi-Gulfport, Miss.	17600	5600	1400	1700
Binghampton, N.Y.	38500	5600	1300	1400
Birmingham, Ala.	86400	22700	5500	6400
Bloomington-Normal, Ill.	11500	2900	700	800
Boise City, Ida.	13800	2600	600	700
Boston, Mass.	316900	39100	9400	9100
Bridgeport, Conn.	46100	4800	1100	1100
Bristol, Conn.	8700	1100	300	300
Brockton, Mass.	27500	3300	800	800
Brownsville-Harlingen-San Benito, Tex.	21800	7700	1800	2600
Bryan-College Station, Tex.	7600	2400	600	800
Buffalo, N.Y.	163000	21900	5200	5300
Canton, Ohio	45700	8000	1900	2100
Cedar Rapids, Iowa	22800	3600	700	900
Champaign-Urbana, Ill.	18400	2600	600	600
Charleston, S.C.	43100	12000	2900	3600
Charleston, W. Va.	25000	6200	1500	1700
Charlotte, N.C.	53900	10500	2500	2800
Chattanooga, Tenn.	36500	9300	2200	2600

Table 35 Continued

SMSA NAME	Children 6 and Under	Children At Risk	Model 1 EBL	Model 1A EBL
Chicago, Ill.	872500	100300	24100	23600
Cincinnati, Ohio-Ky.-Ind.	179700	26700	6400	6800
Cleveland, Ohio	250700	26500	6400	6100
Colorado Springs, Col.	30300	4000	900	1000
Columbia, Missouri	9100	2100	500	600
Columbia, S.C.	38700	8800	2100	2400
Columbus, Ga.	31300	8400	2000	2500
Columbus, Ohio	116000	19600	4700	5100
Corpus Christi, Tex.	40400	9300	2200	2700
Dallas, Tex.	211800	35600	8600	9500
Davenport-Rock Island-Moline, Iowa-Ill.	47600	7900	1900	2100
Dayton, Ohio	108100	13300	3200	3200
Decatur, I-l.	15700	2600	600	700
Denver, Colo.	154700	16900	4100	3900
Des Moines, Iowa	35600	6900	1600	1900
Detroit, Mich.	546200	59100	14100	13900
Dubuque, Iowa	13600	3300	800	1000
Duluth-Superior, Minn.-Wisc.	29600	5600	1400	1500
Durham, N.C.	21900	4800	1200	1300
El Paso, Tex.	52800	10100	2400	2800
Erie, Pa.	33800	5200	1200	1300
Eugene, Ore.	24700	4300	1000	1100
Evansville, Ind.-Ky.	26800	5200	1300	1400
Fall River, Mass.-R.I.	18000	2500	600	600
Fargo-Morehead, N. Dak.-Minn.	14000	2300	500	600
Fayetteville, N.C.	29300	9800	2300	3100
Fitchburg-Leominster, Mass.	12000	3000	700	900
Flint, Mich.	73000	10900	2600	2900
Fort Lauderdale-Hollywood, Fla.	60700	4500	1100	900
Fort Smith, Ark.-Okla.	19800	8100	1900	2600
Fort Wayne, Ind.	38000	5500	1300	1400
Fort Worth, Tex.	99600	16700	4000	4400
Fresno, Cal.	51800	11300	2700	3100
Gadsden, Ala.	11200	4300	1000	1300
Gainesville, Fla.	12400	3800	900	1100
Galveston-Texas City, Texas	21300	4900	1200	1400
Gary-Hammond-East Chicago, Ind.	84700	13000	3100	3400
Grand Rapids, Mich.	72700	9800	2400	2500
Great Falls, Mont.	10700	3100	700	900
Green Bay, Wisc.	23300	3100	800	800
Greensboro-Winston Salem-High Point, N.C.	73500	14500	3500	3900
Greenville, S.C.	37000	9200	2200	2600
Hamilton-Middletown, Ohio	28100	4000	1000	1000
Harrisburg, Pa.	46100	5700	1400	1300

Table 35 Continued

SMSA NAME	Children 6 and Under	Children At Risk	Model 1 EBL	Model 1A EBL
Hartford, Conn.	81900	7200	1700	1600
Honolulu, Hawaii	84900	18100	4300	5100
Houston, Tex.	273300	40300	9700	10400
Huntington-Ashland, W. Va.-Ky.-Ohio	29200	7700	1900	2100
Huntsville, Ala.	32800	7200	1700	2100
Indianapolis, Ind.	145900	21900	5300	5600
Jackson, Mich.	18300	3200	800	800
Jackson, Miss.	34600	8000	1900	2300
Jacksonville, Fla.	66200	13700	3300	3700
Jersey City, N.J.	66600	10300	2500	2500
Johnstown, Pa.	29000	7300	1700	2000
Kalamazoo, Mich.	24500	3600	900	900
Kansas City, Mo.-Kansas	155500	24100	5800	6100
Kenosha, Wisc.	15700	2100	500	500
Knoxville, Tenn.	45200	10800	2600	3000
La Crosse, Wisc.	9400	2300	500	600
Lafayette, La.	16100	4800	1200	1500
Lafayette, West Lafayette, Ind.	13100	3000	700	800
Lake Charles, La.	20100	4100	1000	1200
Lancaster, Pa.	39700	4700	1100	1100
Lansing, Mich.	50700	7800	1900	2000
Laredo, Tex.	12000	6800	1600	2600
Las Vegas, Nev.	37800	3100	800	700
Lawrence-Haverhill, Mass.-N.H.	29300	5000	1200	1300
Lawton, Okla.	13600	2900	700	800
Lewiston-Auburn, Maine	9100	2300	500	700
Lexington, Ky.	21600	4200	1000	1100
Lima, Ohio	22800	4500	1100	1200
Lincoln, Neb.	18900	3800	900	1000
Little Rock-North Little Rock, Ark.	40700	8800	2100	2400
Lorain-Elyria, Ohio	36400	4600	1100	1200
Los Angeles-Long Beach, Cal.	839100	60900	14600	12600
Louisville, Ky.-Ind.	103300	16900	4100	4300
Lowell, Mass.	31600	4600	1100	1200
Lubbock, Tex.	24000	4500	1100	1200
Lynchburg, Va.	14500	3700	900	1100
Macon, Ga.	27100	8000	1900	2400
Madison, Wisc.	36300	3800	900	900
Manchester, N.H.	13100	2600	600	700
Mansfield, Ohio	16600	3800	900	1100
McAllen-Pharr-Edenburg, Tex.	28900	9900	2400	3300
Memphis, Tenn.-Ark.	101000	18800	4500	5100
Meriden, Conn.	6900	1000	200	300
Miami, Fla.	127300	10700	2600	2200

Table 35 Continued

SMSA NAME	Children 6 and Under	Children At Risk	Model 1 EBL	Model 1A EBL
Midland, Tex.	8100	1500	400	400
Milwaukee, Wisc.	177600	17600	4200	4000
Minneapolis-St. Paul, Minn.	244400	27900	6700	6700
Mobile, Ala.	50300	14000	3400	4200
Modesto, Cal.	24200	3100	700	800
Monroe, La.	15900	5100	1200	1600
Montgomery, Ala.	26000	7200	1700	2100
Muncie, Ind.	16400	2900	700	700
Muskegon-Muskegon Heights, Mich.	20900	3500	800	900
Nashua, N.H.	10200	1800	400	500
Nashville, Tenn.	63700	13000	3100	3500
New Bedford, Mass.	16800	2000	500	500
New Britain, Conn.	16900	1700	400	400
New Haven, Conn.	40800	5400	1300	1300
New London-Groton-Norwich, Conn.	27800	4500	1100	1200
New Orleans, La.	140300	30100	7200	8500
New York, N.Y.	1316700	169100	40600	39800
Newark, N.J.	222000	28500	6800	6800
Newport News-Hampton, Va.	38700	6900	1700	1800
Norfolk-Portsmouth, Va.	86300	15200	3600	4000
Norwalk, Conn.	14300	1500	400	300
Odessa, Tex.	12200	2600	600	700
Ogden, Utah	17600	2500	600	600
Oklahoma City, Okla.	78300	13900	3300	3600
Omaha, Nebr.-Iowa	73400	11400	2700	3000
Orlando, Fla.	51600	8000	1900	2000
Owensboro, Ky.	10600	2300	500	600
Oxnard-Ventura, Cal.	53500	8300	2000	2200
Paterson-Clifton-Passaic, N.J.	150500	11400	2700	2300
Pensacola, Fla.	31300	7500	1800	2100
Peoria, Ill.	42700	6800	1600	1700
Petersburg-Colonial Heights, Va.	15900	6500	1600	2100
Philadelphia, Pa.-N.J.	578900	60100	14400	13600
Phoenix, Ariz.	122300	18500	4400	4700
Pine Bluff, Ark.	11700	6000	1400	2100
Pittsburgh, Pa.	259900	43900	10500	10900
Pittsfield, Mass.	9700	1700	400	400
Portland, Maine	16700	2100	500	500
Portland, Ore.-Wash.	116000	17300	4100	4200
Providence-Pawtucket-Warwick, R.I.-Mass.	108400	13400	3200	3200
Provo-Orem, Utah	20200	2600	600	700
Pueblo, Colo.	14200	3500	800	1000
Racine, Wisc.	23500	2900	700	700

Table 35 Continued

SMSA NAME	Children 6 and Under	Children At Risk	Model 1 EBL	Model 1A EBL
Raleigh, N.C.	27900	6600	1600	1900
Reading, Pa.	32000	4100	1000	900
Reno, Nev.	14000	2400	600	600
Richmond, Va.	61300	8400	2000	2000
Roanoke, Va.	20600	2900	700	700
Rochester, Minn.	12300	2200	500	600
Rochester, N.Y.	115800	12700	3000	3000
Rockford, Ill.	37500	5100	1200	1300
Sacramento, Cal.	93700	10600	2500	2400
Saginaw, Mich.	32300	5700	1400	1600
St. Joseph, Mo.	10000	3100	700	900
St. Louis, Mo.-Ill.	294700	47800	11500	12300
Salem, Ore.	20700	5300	1300	1500
Salinas-Monterey, Cal.	30000	2000	500	400
Salt Lake City, Utah	84700	10500	2500	2700
San Angelo, Tex.	8200	1900	500	500
San Antonio, Tex.	117900	25000	6000	7000
San Bernardino-Riverside-Ontario, Cal.	142200	17600	4200	4200
San Diego, Cal.	156400	13500	3300	2900
San Francisco-Oakland, Cal.	336800	29200	7000	6200
San Jose, Cal.	143300	11400	2700	2500
Santa Barbara, Cal.	30500	3400	800	800
Santa Rosa, Cal.	23600	3400	800	800
Savannah, Ga.	24000	6200	1500	1800
Scranton, Pa.	23600	4300	1000	1100
Seattle-Everett, Wash.	172800	22100	5300	5300
Shreveport, La.	39200	10000	2400	2900
Sioux City, Iowa-Neb.	14100	3700	900	1100
Sioux Falls, South Dakota	12000	2400	600	700
South Bend, Ind.	33500	4100	1000	1000
Spokane, Wash.	22900	4900	1200	1200
Springfield, Ill.	19400	3600	900	900
Springfield, Mo.	17300	3200	800	800
Springfield, Ohio	20500	3800	900	1000
Springfield-Chicopee-Holyoke, Mass.-Conn.	62000	8200	2000	1900
Stamford, Conn.	22200	1800	400	300
Steubenville-Wierton, Ohio-W. Va.	18800	4200	1000	1100
Stockton, Cal.	34500	6400	1500	1700

Table 35 Continued

SMSA NAME	Children 6 and Under	Children At Risk	Model 1 EBL	Model 1A EBL
Syracuse, N.Y.	83600	14000	3400	3700
Tacoma, Wash.	48300	7200	1700	1800
Tallahassee, Fla.	12200	3700	900	1100
Tampa-St. Petersburg, Fla.	99000	12800	3100	2900
Terre Haute, Ind.	18600	4900	1200	1300
Texarkana, Tex.-Ark.	12600	5400	1300	1800
Toledo, Ohio-Mich.	88300	11600	2800	2800
Topeka, Kansas	19000	3400	800	900
Trenton, N.J.	34800	3800	900	900
Tucson, Ariz.	41600	5600	1300	1300
Tulsa, Okla.	57900	11900	2900	3200
Tuscaloosa, Ala.	12900	4300	1000	1300
Tyler, Tex.	11900	4100	1000	1300
Utica-Rome, N.Y.	42500	8900	2100	2400
Vallejo-Napa, Cal.	30400	5200	1200	1300
Vineland-Millville-Bridgeton, N.J.	16100	3400	800	1000
Waco, Tex.	15600	3700	900	1000
Washington, D.C.-Md.-Va.	370000	26300	6300	5600
Waterbury, Conn.	26200	3000	700	700
Waterloo, Iowa	16900	2700	600	700
West Palm Beach, Fla.	36900	5300	1300	1300
Wheeling, W. Va.-Ohio	19500	4800	1200	1300
Wichita, Kansas	48700	7300	1700	1800
Wichita Falls, Tex.	14200	3100	700	800
Wilkes Barre-Hazleton, Pa.	34200	5100	1200	1200
Wilmington, Del.-N.J.-Md.	64700	8400	2000	2100
Wilmington, N.C.	13800	4600	1100	1400
Worcester, Mass.	39600	5300	1300	1300
York, Pa.	40100	5000	1200	1200
Youngstown-Warren, Ohio	63200	9800	2400	2400
Total for all SMSA's	17112800	2458100	590000	624100

All numbers have been rounded to the nearest hundred. The totals are rounded after summing, rather than being sums of the rounded numbers.

PREDICTED NATION-WIDE INCIDENCE OF LEAD BASED PAINT POISONING

25 SMSA'S WITH GREATEST PREDICTED INCIDENCE

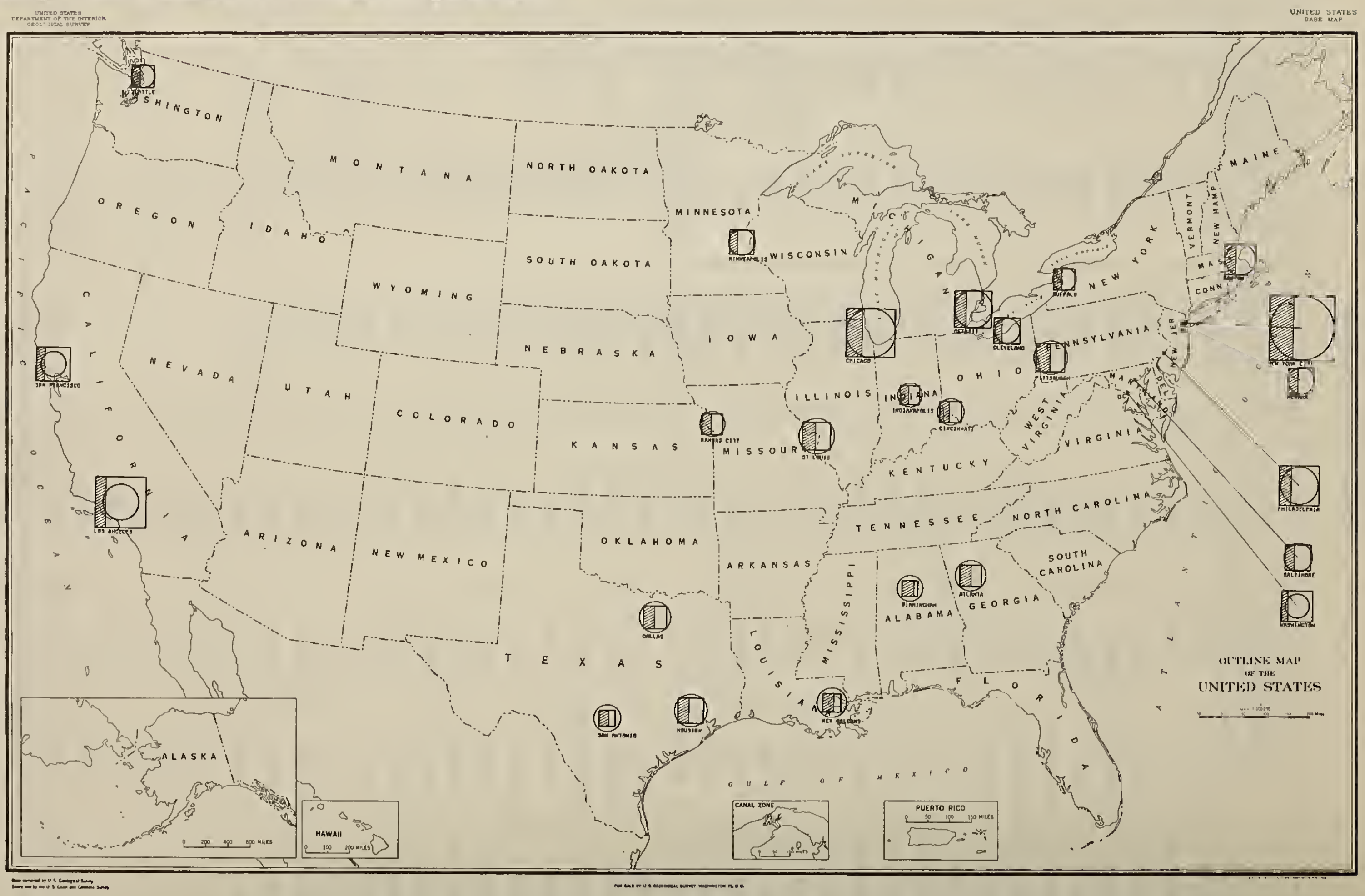
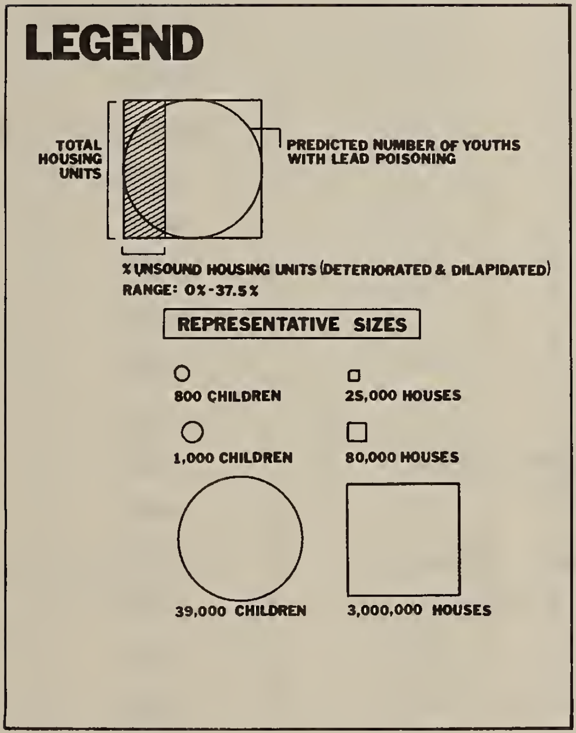


Figure 4

Figure 4 Continued



PREPARED BY:

APPLIED
URBANETICS,
INC.

Table 36

25 SMSA's With the Greatest Number of EBL's (Model 1 Estimates)

SMSA	EBL	Population Rank
1. New York, N.Y.	40600	1
2. Chicago, Ill.	24100	3
3. Los Angeles - Long Beach, Cal.	14600	2
4. Philadelphia, Pa.	14400	4
5. Detroit, Mich.	14200	5
6. St. Louis, Mo.-Ill.	11500	10
7. Pittsburgh, Pa.	10500	9
8. Houston, Tex.	9700	13
9. Boston, Mass.	9400	8
10. Dallas, Tex.	8600	16
11. Atlanta, Ga.	8100	19
12. Baltimore, Md.	7800	11
13. New Orleans, La.	7200	30
14. San Francisco-Oakland, Cal.	7000	6
15. Newark, N.J.	6800	14
16. Minneapolis-St. Paul, Minn.	6700	15
17. Cincinnati, Ohio-Ky.-Ind.	6400	20
18. Cleveland, Ohio	6400	12
19. Washington, D.C.-Md.-Va.	6300	7
20. San Antonio, Tex.	6000	37
21. Kansas City, Kan.-Mo.	5800	25
22. Birmingham, Ala.	5500	43
23. Seattle-Everett, Wash.	5300	18
24. Indianapolis, Ind.	5300	28
25. Buffalo, N.Y.	5200	23
Total	253400	

Table 37

The Number of Children in Each SMSA with Blood Lead Levels of 40 and Above, 50 and Above, 60 and Above, and 70 and Above (Measured in μg/100 ml; based on 1970 New York City EBL rates)

SMSA NAME	40 And Above	50 And Above	60 And Above	70 And Above
Abilene, Tex.	800	400	160	80
Akron, Ohio	3300	1500	690	310
Albany, Ga.	1300	600	260	120
Albany-Schenectady-Troy, N.Y.	4000	1800	840	380
Albuquerque, N. Mex.	1500	700	310	140
Allentown-Bethlehem-Easton, Pa.-N.J.	2000	900	430	200
Altoona, Pa.	1200	500	250	110
Amarillo, Tex.	800	400	170	80
Anaheim-Santa Ana-Garden Grove, Cal.	3600	1600	750	340
Anderson, Ind.	1200	500	250	110
Ann Arbor, Mich.	1000	500	220	100
Appleton-Oshkosh, Wisc.	1700	700	350	160
Asheville, N.C.	1300	600	270	120
Atlanta, Ga.	9700	4300	2020	910
Atlantic City, N.J.	700	300	150	70
Augusta, Ga.	2500	1100	510	230
Austin, Tex.	1900	900	400	180
Bakersfield, Cal.	2600	1200	540	250
Baltimore, Md.	9400	4100	1950	880
Baton Rouge, La.	2200	1000	470	210
Bay City, Mich.	900	300	180	80
Beaumont-Port Arthur-Orange, Tex.	2400	1100	510	230
Billings, Mont.	700	300	150	70
Biloxi-Gulfport, Miss.	1600	700	340	150
Binghampton, N.Y.	1600	700	340	150
Birmingham, Ala.	6500	2900	1360	610
Bloomington-Normal, Ill.	800	400	170	80
Boise City, Idaho	800	300	160	70
Boston, Mass.	11300	5000	2350	1060
Bridgeport, Conn.	1400	600	290	130
Bristol, Conn.	300	100	60	300
Brocton, Mass.	900	400	200	90
Brownsville-Harlingen-San Benito, Tex.	2200	1000	460	200
Bryan-College Station, Tex.	700	300	150	60
Buffalo, N.Y.	6300	2800	1310	590
Canton, Ohio	2300	1000	480	220
Cedar Rapids, Iowa	1000	500	220	100
Champaign-Urbana, Ill.	700	300	150	70
Charleston, S.C.	3500	1500	720	320
Charleston, W. Va.	1800	800	370	170

Table 37 Continued

SMSA NAME	40 And Above	50 And Above	60 And Above	70 And Above
Charlotte, N.C.	3000	1300	630	280
Chatenooga, Tenn.	2700	1100	560	250
Chicago, Ill.	28900	12700	6020	2710
Cincinnati, Ohio-Ky.-Ind.	7700	3400	1600	720
Cleveland, Ohio	7600	3400	1600	720
Colorado Springs, Colo.	1100	500	240	110
Columbia, Mo.	600	300	130	60
Columbia, S.C.	2500	1100	530	240
Columbus, Ga.	2400	1100	500	230
Columbus, Ohio	5700	2500	1180	530
Corpus Christi, Tex.	2700	1200	560	250
Dallas, Tex.	10300	4500	2140	960
Davenport-Rock Island-Moline, Iowa-Ill.	2300	1000	470	210
Dayton, Ohio	3800	1700	800	360
Decatur, Ill.	800	300	160	70
Denver, Colo.	4900	2200	1020	460
Des Moines, Iowa	2000	900	420	190
Detroit, Mich.	7000	7500	3550	1600
Dubuque, Iowa	1000	400	200	90
Duluth-Superior, Minn-Wisc.	1600	700	340	150
Durham, N.C.	1400	600	290	130
El Paso, Tex.	2900	1300	610	270
Erie, Pa.	1500	700	310	140
Eugene, Ore.	1300	600	260	120
Evansville, Ind.-Ky.	1500	700	310	140
Fall River, Mass.-R.I.	700	300	150	70
Fargo-Morehead, N. Dak.-Minn.	700	300	140	60
Fayetteville, N.C.	2800	1200	590	260
Fitchburg-Leominster, Mass.	900	400	180	80
Flint, Mich.	3100	1400	650	290
Fort Lauderdale-Hollywood, Fla.	1300	600	270	120
Fort Smith, Ark.-Okla.	2300	1000	480	220
Fort Wayne, Ind.	1600	700	330	150
Fort Worth, Tex.	4800	2100	1000	450
Fresno, Cal.	3200	1400	680	300
Gadsden, Ala.	1200	500	260	120
Gainesville, Fla.	1100	500	230	100
Galveston-Texas City, Tex.	1400	600	290	130
Gary-Hammond-East Chicago, Ind.	3800	1700	780	350
Grand Rapids, Mich.	2800	1200	590	270
Great Falls, Mont.	900	400	190	80
Green Bay, Wisc.	900	400	190	90

Table 37 Continued

SMSA NAME	40 AND ABOVE	50 AND ABOVE	60 AND ABOVE	70 AND ABOVE
Greensboro-Winston Salem-High Point, N.C.	4200	1800	870	390
Greenville, S.C.	2700	1200	550	250
Hamilton-Middletown, Ohio	1100	500	240	110
Harrisburg, Pa.	1600	700	340	150
Hartford, Conn.	2100	900	430	190
Honolulu, Hawaii	5200	2300	1090	490
Houston, Tex.	11600	5100	2420	1090
Huntington-Ashland, W.Va.-Ky.-Ohio	2200	1000	460	210
Huntsville, Ala.	2100	900	440	200
Indianapolis, Ind.	6300	2800	1320	590
Jackson, Mich.	900	400	190	90
Jackson, Miss.	2300	1000	480	220
Jacksonville, Fla.	3900	1700	820	370
Jersey City, N.J.	3000	1300	620	280
Johnstown, Pa.	2100	900	440	200
Kalamazoo, Mich.	1000	500	210	100
Kansas City, Mo.-Kansas	6900	3100	1450	650
Kenosha, Wisc.	600	300	130	60
Knoxville, Tenn.	3100	1400	650	290
La Crosse, Wisc.	700	300	140	60
Lafayette, La.	1400	600	290	130
Lafayette, West Lafayette, Ind.	900	400	180	80
Lake Charles, La.	1200	500	250	110
Lancaster, Pa.	1300	600	280	130
Lansing, Mich.	2300	1000	470	210
Laredo, Tex.	2000	900	410	180
Las Vegas, Nev.	900	400	190	90
Lawrence-Haverhill, Mass.	1400	600	300	130
Lawton, Okla.	800	400	180	80
Lewiston-Auburn, Maine	700	300	140	60
Lexington, Ky.	1200	500	260	120
Lima, Ohio	1300	600	270	120
Lincoln, Neb.	1100	500	230	100
Little Rock-North Little Rock, Ark.	2500	1100	530	240
Lorain-Elyria, Ohio	1300	600	280	130
Los Angeles-Long Beach, Cal.	17500	7700	3650	1640
Louisville, Ky.-Ind.	4900	2100	1010	460
Lowell, Mass.	1300	600	270	120
Lubbock, Tex.	1300	600	270	120
Lynchburg, Va.	1100	500	220	100
Macon, Ga.	2300	1000	480	220
Madison, Wisc.	1100	500	230	100
Manchester, N.H.	800	300	160	70

SMSA NAME	40 AND ABOVE	50 AND ABOVE	60 AND ABOVE	70 AND ABOVE
Mansfield, Ohio	1100	500	230	100
McAllen-Pharr-Edenburg, Tex.	2900	1300	600	270
Memphis, Tenn.-Ark.	5400	2400	1130	510
Meriden, Conn.	300	100	60	30
Miami, Fla.	3100	1400	640	290
Midland, Tex.	400	200	90	40
Milwaukee, Wisc.	5100	2200	1060	480
Minneapolis-St. Paul, Minn.	8000	3500	1670	750
Mobile, Ala.	4000	1800	830	380
Modesto, Cal.	900	400	190	80
Monroe, La.	1500	600	300	140
Montgomery, Ala.	2100	900	430	190
Muncie, Ind.	800	400	170	80
Muskegon-Muskegon Heights, Mich.	1000	400	210	90
Nashua, N.H.	500	200	110	50
Nashville, Tenn.	3700	1600	780	350
New Bedford, Mass.	600	300	120	50
New Britain, Conn.	500	200	100	50
New Haven, Conn.	1600	700	320	150
New London-Groton-Norwich, Conn.	1300	600	270	120
New Orleans, La.	8700	3800	1800	810
New York, N.Y.	48700	21500	10150	4570
Newark, N.J.	8200	3600	1710	770
Newport News-Hampton, Va.	2000	900	410	190
Norfolk-Portsmouth, Va.	4400	1900	910	410
Norwalk, Conn.	400	200	90	40
Odessa, Tex.	700	300	150	70
Ogden, Utah	700	300	150	70
Oklahoma City, Okla.	4000	1800	830	370
Omaha, Nebr.-Iowa.	3300	1500	690	310
Orlando, Fla.	2300	1000	480	220
Owensboro, Ky.	700	300	140	60
Oxnard-Ventura, Cal.	2400	1100	500	230
Paterson-Clifton-Passaic, N.J.	3300	1400	680	310
Pensacola, Fla.	2200	1000	450	200
Peoria, Ill.	1900	900	410	180
Petersburg-Colonial Heights, Va.	1900	800	400	180
Philadelphia, Pa.-N.J.	17300	7600	3610	1620
Phoenix, Ariz.	5300	2400	1110	500
Pine Bluff, Ark.	1700	800	360	160
Pittsburgh, Pa.	12600	5600	2640	1190
Pittsfield, Mass.	500	200	100	50
Portland, Maine.	600	300	130	60

Table 37, Continued

SMSA NAME	40 AND ABOVE	50 AND ABOVE	60 AND ABOVE	70 AND ABOVE
Portland, Ore.-Wash.	5000	2200	1040	470
Providence-Pawtucket-Warrwick, R.I.-Mass.	3800	1700	800	360
Provo-Orem, Utah	800	300	160	70
Pueblo, Colo.	1000	400	210	100
Racine, Wisc.	800	400	180	80
Raleigh, N.C.	1900	800	400	180
Reading, Pa.	1200	500	250	110
Reno, Nev.	700	300	140	60
Richmond, Va.	2400	1100	500	230
Roanoke, Va.	800	400	180	80
Rochester, Minn.	600	300	130	60
Rochester, N.Y.	3600	1600	760	340
Rockford, Ill.	1500	700	310	140
Sacramento, Cal.	3100	1300	640	290
Saginaw, Mich.	1600	700	340	150
St. Joseph, Mo.	900	400	180	80
St. Louis, Mo.-Ill.	13800	6100	2870	1290
Salem, Ore.	1500	700	320	140
Salinas-Monterey, Cal.	600	300	120	50
Salt Lake City, Utah	3000	1300	630	280
San Angelo, Tex.	500	200	110	50
San Antonio, Tex.	7200	3200	1500	680
San Bernardino-Riverside-Ontario, Cal.	5100	2200	1060	480
San Diego, Cal.	3900	1700	810	370
San Francisco-Oakland, Cal.	8400	3700	1750	790
San Jose, Cal.	3300	1400	680	310
Santa Barbara, Cal.	1000	400	200	90
Santa Rosa, Cal.	1000	400	210	90
Savannah, Ga.	1800	800	370	170
Scranton, Pa.	1200	600	260	120
Seattle-Everett, Wash.	6400	2800	1330	600
Shreveport, La.	2900	1300	60	270
Sioux City, Iowa-Neb.	1100	500	220	100
Sioux Falls, S. Dak.	700	300	150	70
South Bend, Ind.	1200	500	250	110
Spokane, Wash.	1400	600	290	130
Springfield, Ill.	1000	500	210	100
Springfield, Mo.	900	400	190	90
Springfield, Ohio	1100	500	230	100
Springfield-Chicopee-Holyoke, Mass.-Conn.	2300	1000	490	220
Stamford, Conn.	500	200	110	50
Stubbenville-Wierton, Ohio-W. Va.	1200	500	250	110
Stockton, Cal.	1800	800	380	170

Table 37 Continued

SMSA NAME	40 AND ABOVE	50 AND ABOVE	60 AND ABOVE	70 AND ABOVE
Syracuse, N.Y.	4000	1800	840	380
Tacoma, Wash.	2100	900	430	190
Tallahassee, Fla.	1100	500	230	100
Tampa-St. Petersburg, Fla.	3700	1600	770	350
Terre Haute, Ind.	1400	600	290	130
Texarkana, Tex.-Ark.	1600	700	320	150
Toledo, Ohio-Mich.	3300	1500	700	310
Topeka, Kansas	1000	400	210	90
Trenton, N.J.	1100	500	230	100
Tucson, Ariz.	1600	700	330	150
Tulsa, Okla.	3400	1500	720	320
Tuscaloosa, Ala.	1200	500	260	120
Tyler, Tex.	1200	500	250	110
Utica-Rome, N.Y.	2600	1100	530	240
Vallejo-Napa, Cal.	1500	700	310	140
Vineland-Millville-Bridgeton, N.J.	1000	400	210	90
Waco, Tex.	1100	500	220	100
Washington, D.C.-Md.-Va.	7600	3300	1580	710
Waterbury, Conn.	900	400	180	80
Waterloo, Iowa	800	300	160	70
West Palm Beach, Fla.	1500	700	320	140
Wheeling, W. Va.-Ohio	1400	600	290	130
Wichita, Kansas	2100	900	440	200
Wichita, Falls, Tex.	900	400	190	80
Wilkes Barre-Hazleton, Pa.	1500	700	310	140
Wilmington, Del.-N.J.-Md.	2400	1100	500	230
Wilmington, N.C.	1300	600	280	130
Worcester, Mass.	1500	700	320	140
York, Pa.	1400	600	300	130
Youngstown-Warren, Ohio	2800	1200	590	270
Total for all SMSA's	708000	312200	147490	66370

The columns for 40 and above and 50 and above have been rounded to the nearest hundred; those for 60 and above and 70 and above to the nearest ten. The totals have been rounded after summing. The fact that the last two columns have been rounded to the nearest 10 should not be taken as an indication of a greater precision in these estimates. The rounding for these columns was chosen to allow comparisons between estimates for different SMSA's, which would have been blurred if they were rounded to the nearest hundred.

and above, and 2.7% for 70 and above. We note that the percentage of EBL's observed in the New York program is greater by 4.8 percentage points than the average figure which was used in the calculations of the model 1 estimates given in table 35. This higher New York EBL rate leads to an alternative national estimate of 700,000 EBL's, 300,000 of which are at a level of 50 μg/100 ml or more, 150,000 of which are 60 or more, and 66,000 of which are at the level of 70 μg/100 ml or more. In this table the estimates for 40 and above and 50 and above have been rounded to the nearest hundred, indicating as before the approximate nature of the numbers. The estimates for 60 and above and 70 and above have been rounded to the nearest 10, which should not be taken to mean that these estimates are more precise than the others. It was done because the magnitudes of the numbers are close to one hundred and rounding would blur comparisons. (For example, 149 is almost 3 times 51 but both would round to 100.)

As noted earlier, the estimates given in this report are at best as good as the data and information currently available, and information is lacking in several areas. Therefore the estimates produced must be assessed with these data lacks in mind. We have assumed in formulating the models that the primary cause of pediatric lead poisoning is the ingestion of old lead based paint. There is some evidence supporting this view, such as the fact that lead often shows up in X-rays of the stomach and intestines of poisoned children, and the high correlation between EBL and the condition of the child's house discovered in the analysis of the Aurora data. However, some experts have emphasized air pollution (particularly leaded gasoline fumes) as a causative factor.

citing the lower average blood lead level for rural children as evidence of its importance. Thus to really insure a solution to the problem of lead poisoning as well as to assess its magnitude, it is necessary to know, with more certainty than is now known, what are the sources of the lead and how much each contributes to the poisoning problem.

To date, lead poisoning has been found primarily among the poor inner city dwellers of the Northeast and Midwest. On the other hand, it has often been noted that the number of cases found is in direct proportion to the effort spent looking for them, and so far they have generally been sought within this group. To fully assess the extent of the problem, it is thus necessary to screen middle income children, rural children, and children in the South and West to estimate EBL rates among these groups. The current estimates must be viewed with reservation in the absence of such additional screening information.

The estimates given in this report confirm that pediatric lead poisoning is a major urban health problem in this country. The models suggest that if tested, approximately 600,000 children would show undue absorption of lead, as measured by the level of lead in their blood. The effects of this, in terms of the number of children suffering permanent brain damage or damage to other organs, is not known. How many of the children who have only slightly elevated blood levels will later on exhibit learning difficulties is not known, but it is believed that the problem will persist as long as peeling lead painted surfaces are ascessible to young children. Discovering and treating children with EBL's will partially alleviate the problem, but its full solution requires the removal of lead paint on all surfaces accessible to children.

APPENDIX A

OTHER MODELS

This appendix documents several trial models formulated in the course of model development, but rejected in favor of the two given in Chapter 3. They are similar in form to the favored models, differing chiefly in the combination of parameters employed. In the primitive screening process by which the models were selected, we relied principally on the ability of the models to reproduce the data observations, and on the intuitive plausibility of the signs of coefficients or exponents. We termed a fit "good" if $R^2 \geq .9$, and signs "wrong" if they were opposite to those expected. These criteria are discussed at greater length in Section 3.3. of the main report.

Table 38 lists the symbols used in the models.

A.1. Model 2

The versions of Model 2 are exponential in form and all use unsound housing as a variable.

A.1.1. Model 2.1.

$$E = a_0 \left(\frac{F}{P}\right)^{a_1} \left(\frac{D}{H}\right)^{a_2} \left(\frac{K_4}{P}\right)^{a_3} \left(\frac{C_{151}}{H}\right)^{a_4}$$

Table 38

Variables and Symbols Used in the Models

$a_0, a_1, \ldots$	parameters estimated by the curve fitting process
C_{101}	crowded population (≥ 1.01 per room)
C_{151}	crowded population (≥ 1.51 per room)
C_F	crowded (1.01) population with female household head
D	dilapidated or deteriorating housing units (number)
E	number of children with elevated blood lead levels (≥ 40 μg/100 ml.)
F	number of female household heads
H	number of housing units
I	fraction of high risk child population with elevated blood lead levels
K_4	number of children 4 years old or younger
K_6	number of children 6 years old or younger
L	number of housing units lacking one or more plumbing facilities
P	total population
R	median rent $/mo.
R_{40}	number of units with rent ≤ $40
R_{60}	number of units with rent ≤ $60
Y	median family income $/ann.

where $a_0 = e^{-2.222}$

$a_1 = .3197$

$a_2 = .1305$

$a_3 = -.7846$

$a_4 = 1.757$

$R^2 = .719$

The fit of this model is not too good and a_3 has the wrong sign, since one would expect areas with more young children to have a higher incidence of lead poisoning.

A.1.2. Model 2.2

$$E = a_0 \left(\frac{F}{P}\right)^{a_1} \left(\frac{D}{H}\right)^{a_2} \left(\frac{K_4}{P}\right)^{a_3} (C_{151})^{a_4}$$

where $a_0 = e^{-3.912}$

$a_1 = -.1911$

$a_2 = .3232$

$a_3 = .1969$

$a_4 = 1.052$

$R^2 = .955$

Although the fit for this model is very good, the sign of a_1 is wrong.

A.1.3. Model 2.3

$$E = a_0 \left(\frac{F}{P}\right)^{a_1} \left(\frac{D}{H}\right)^{a_2} (Y)^{a_3} \left(\frac{K_4}{P}\right)^{a_4} (C_{151})^{a_5}$$

where $a_0 = e^{12.798}$

$a_1 = -.6470$

$a_2 = .3483$

$a_3 = -2.1726$

$a_4 = .4338$

$a_5 = .9413$

$R^2 = .960$

Although the fit is quite good, the sign of a_1 is wrong.

A.1.4. Model 2.4

$$I = a_0\left(\frac{F}{P}\right)^{a_1}\left(\frac{D}{H}\right)^{a_2}(Y)^{a_3}\left(\frac{K_4}{P}\right)^{a_4}(C_{151})^{a_5}$$

where $a_0 = e^{6.895}$

$a_1 = -.4757$

$a_2 = .3560$

$a_3 = -.9926$

$a_4 = .2663$

$a_5 = -.3433$

$R^2 = .960$

Although the fit is quite good, the signs of both a_1 and a_5 are wrong.

A.1.5. Model 2.5

$$I = a_0\left(\frac{K_6}{P}\right)^{a_1}\left(\frac{F}{P}\right)^{a_2}\left(\frac{D}{H}\right)^{a_3}(Y)^{a_4}\left(\frac{C_{101}}{P}\right)^{a_5}$$

where $a_0 = e^{7.654}$

$a_1 = .9697$

$a_2 = -.5163$

$a_3 = .3113$

$a_4 = -.9008$

$a_5 = -.374$

$R^2 = .967$

Although the fit is quite good, the signs of a_1 and a_5 are wrong.

A.1.6. Model 2.6

$$I = a_0 \left(\frac{K_6}{P}\right)^{a_1} \left(\frac{F}{P}\right)^{a_2} \left(\frac{D}{H}\right)^{a_3} (R)^{a_4} \left(\frac{C_{101}}{P}\right)^{a_5}$$

where $a_0 = e^{2.4785}$

$a_1 = .8806$

$a_2 = -.3186$

$a_3 = .3062$

$a_4 = .3062$

$a_5 = -.6908$

$R^2 = .967$

Although the fit is quite good, the signs of a_2 and a_5 are wrong.

A.1.7. Model 2.7

$$I = a_0 \left(\frac{K_6}{P}\right)^{a_1} \left(\frac{F}{P}\right)^{a_2} \left(\frac{D}{H}\right)^{a_3} R^{a_4}$$

where $a_0 = e^{.5306}$

$a_1 = .6416$

$a_2 = -.4574$

$a_3 = .3001$

$a_4 = .1729$

$R^2 = .963$

Although the fit is quite good, the signs of a_2 and a_4 are wrong.

A.1.8. Model 2.8

$$I = a_0\left(\frac{K_6}{P}\right)^{a_1}\left(\frac{D}{H}\right)^{a_2}(R)^{a_3}$$

where $a_0 = e^{-.3362}$

$a_1 = .3003$

$a_2 = .2485$

$a_3 = .0129$

$R^2 = .945$

Although the fit is quite good, the sign of a_3 is wrong.

A.2. Model 3

All of the versions of Models 1 and 2 involved a housing quality variable. However, because data on this factor were not collected in the 1970 Census, an attempt was made to construct a model using only currently available 1970 Census First Count Data items.

A.2.1. Model 3.1

$$I = a_0 \left(\frac{K_6}{P}\right)^{a_1} (L)^{a_2}$$

where $a_0 = e^{.8428}$

$a_1 = .6747$

$a_2 = .2479$

$R^2 = .908$

The fit is good and the signs of all parameters are correct.

A.2.2. Model 3.2

$$I = a_0 \left(\frac{K_6}{P}\right)^{a_1} (L)^{a_2} \left(\frac{C_F}{P}\right)^{a_3}$$

where $a_0 = e^{.8853}$

$a_1 = .5825$

$a_2 = .0712$

$a_3 = .2354$

$R^2 = .908$

The fit is good and all signs of parameters are correct. However the third factor only reduces the residual sum of squares .03 from model 3.1, so that is the preferred model.

A.2.3. Model 3.3

$$I = a_0 \left(\frac{K_6}{P}\right)^{a_1} (L)^{a_2} \left(\frac{C_F}{P}\right)^{a_3} (R_{40})^{a_4}$$

where $a_0 = e^{1.9422}$

$a_1 = .6104$

$a_2 = .4743$

$a_3 = .3481$

$a_4 = -.3603$

$R^2 = .921$

Although the residual sum of squares has been reduced from Model 3.2, the sign of a_4 is wrong.

A.2.4. Model 3.4

$$I = a_0 \left(\frac{K_6}{P}\right)^{a_1} (L)^{a_2} \left(\frac{C_F}{P}\right)^{a_3} (R_{60})^{a_4}$$

where $a_0 = e^{1.6604}$

$a_1 = .6869$

$a_2 = .3898$

$a_3 = .1670$

$a_4 = -.2349$

$R^2 = .933$

This fit was done as a weighted regression where the weight for each census tract was the fraction of its total child population that was screened. The sign of a_4 is wrong.

APPENDIX B

MODELS AND ESTIMATES OF HAZARDOUS HOUSING

B.1. Model Used to Update the New Haven 1960 Housing Condition Data

To remedy the discontinuation in 1970 of tabulation of "condition of housing" data, the Census Bureau has developed a method for predicting that information from the 1970 data and 1960 Fourth Count Census items including (1) units with central heating facilities, (2) rent, (3) units with crowded population; 1.01 or more per room, (4) multiple unit structures, (5) educational level of household head, (6) race of household head, (7) owned or rented, and (8) vacant units. The dwelling units are divided into categories determined by cutoff levels of the above attributes, and separate growth patterns are applied to each of the categories. However, since the Census Fourth Count data were not available in time, this model could not be used to furnish inputs to the lead poisoning models at the present stage.

The following make-shift housing adjustment, therefore, was applied to the census tract level data, on the assumption that the results, even though crude, were more likely than raw 1960 condition of housing figures to be consistent with available 1970 EBL incidence data from New Haven tracts.

Let: H_{60} - total 1960 housing units

H_{70} - total 1970 housing units

D_{60} - total 1960 unsound units

D_{70} - total 1970 unsound units

If $H_{70} \geq H_{60}$, then

$$D_{70} = D_{60}.$$

If $H_{70} < H_{60}$, then

$$D_{70} = \max\ [.05D_{60}, (D_{60} - .9(H_{60} - H_{70}))].$$

This means that if the number of housing units in a tract has increased, we don't attempt to adjust the number of unsound units. If housing has decreased, we assumed that 90 percent of the decrease represents demolition of unsound housing. If "net demolitions", however, appear to exceed the total 1960 unsound housing stock, then 5 percent of this unsound stock was assumed still standing. The choices of the .05 and .9 are arbitrary but have been chosen to approximate patterns stated to exist in New Haven.[34] (This "model" could not be applied usefully at the SMSA level; it would predict "no change" in unsound stock since almost all SMSA's, as opposed to tracts, have experienced net housing increases in the last 10 years. Units demolished in the central cities are more than counter-balanced by those built in the suburbs.) Thus the housing figures used in the modeling process are not as current as one would desire and may be altered in future modeling procedures.

B.2. A Model for Estimating the Volume of Housing Containing Lead Paint

In response to a request from the Department of Housing and Urban Development, the present study includes a method for rough estimation of housing units in each SMSA believed to contain sufficient concentrations of lead on painted surfaces to constitute lead poisoning hazards. (Although this estimated number of "hazardous environments" has not yet been incorporated as a variable into the EBL models tested, the formulation of the method is presented here to make the current record complete.)

The housing estimation embodies the following assumptions:

(1) Almost all housing units constructed before 1940 in urbanized regions contain lead paint from original surfacing and/or subsequent refurbishment.

(2) About half of the housing units built between 1940 and 1949 in urbanized areas are similarly contaminated. (This is an informal estimate based on the reduction in the quantity of lead paint manufactured in this decade, relative to housing construction in the same period.)[35]

(3) Only 5% of housing constructed between 1950 and 1959 has interior lead paint, and post 1960 housing can be ignored in the estimates.

(4) Areas in which non-negligible fractions of the housing stock were largely unpainted or merely whitewashed (substantially in the rural South) or other areas in which the climate allowed painting materials to be selected without great concern for weathering properties (such as the south west and far west) can be distinguished crudely from high hazard concentration areas by differences in the fraction of dwelling units which are single unit structures.

Reasoning from (4) above, the estimates by age in (1), (2), and (3) are attenuated in the model by the fourth root of the fraction of dwelling units in multi-unit structures. (Weighting by the actual fractions of multi-unit structures leads to counts of contaminated dwelling units which are suspiciously low, so they have been adjusted upward by using the fourth root, the square root of the square root, of these fractions. The fourth root has desirable properties of being easy to calculate, and remaining smaller than 1.0 for fractions. It also compresses the range of the weights.) Typical values of the fraction of total dwelling units which are in multiunit buildings in southern cities and SMSA's[36] are .3 and .2, respectively, in northeastern cities and SMSA's, .7 and .5 respectively. The fourth roots of these numbers are, in the order listed, .74, .67, .91, and .84.

The count of housing units by age in each SMSA has to be estimated, because while 1970 national figures for % of housing by decade of construction have been published by the Bureau of the Census, counts by SMSA were not available in time to be utilized in this effort. The estimates are made by multiplying the 1960 census counts by the ratios of national percentages in 1960 and 1970. Thus the estimate has the form

$$HL = \sqrt[4]{M}\left(H_{40/60}\frac{h_{40/70}}{h_{40/60}} + .5H_{50/60}\frac{h_{50/70}}{h_{50/60}} + .5H_{60/60}\frac{h_{60/70}}{h_{60/60}}\right)$$

where: HL is the estimated number of contaminated housing units in an SMSA

$H_{40/60}$, $H_{50/60}$, $H_{60/60}$ are the counts of 1960 housing stock in the SMSA built before 1940, during 1940-49, and during 1950-59, according to 1960 census data.

$h_{40/60}$, $h_{50/60}$, $h_{60/60}$ are the fractions of the 1960 national housing stock built before 1940, during 1940-49, and during 1950-59, according to 1960 census data

$h_{40/70}$, $h_{50/70}$, $h_{60/70}$ are the fractions of the 1970 national housing stock built before 1940, during 1940-49 and during 1950-59, according to 1970 census data.

B.3. Estimate of the Nationwide Number of Housing Units Containing Lead Paint

Because of the late release of the 1970 Fourth Count Census data, the model described in B.2 was not applied for each SMSA. The nationwide total of potentially hazardous housing was desired, however, so an attempt was made to estimate it using a different procedure.

Although we know that some housing built before 1940 may be uncontaminated by interior lead paint, and that a nonnegligible portion of housing built in 1950-1959 does include lead paint-bearing surfaces (as well as some built after 1960), we have relied, as a rule of thumb, on the supposition that the potentially "lead hazardous" housing stock is substantially equivalent to the standing stock built before 1940.

Bureau of Census publication Current Housing Reports--Housing Vacancies (Series H-111, No. 63, Part II, March 1971), contains on page 2 the following statements:

> "Two-fifths of the 1970 stock of homeowner housing were at least 30 years old"

"About 55 percent of the rental units were at least 30 years old"

The following data were provided by the Housing Division of the Bureau of Census in a telephone conversation on January 5, 1972.

A - Total H.U.	67 656 566
B - Total occupied	63 449 747
C - Renter occupied	23 564 567
D - Vacant for rent	1 655 390
E - Owner occupied	39 885 180
F - Vacant owner units	477 371
G - Rented or sold-awaiting occupancy	334 295
H - Occasional use units	760 237
J - Otherwise year round vacant	979 526

Using these data and the estimated rates quoted above, we have the following formulations:

Pre 1940 occupied or awaiting occupancy:

$$.55(C + .37G) + .4(E + .63G) = 29{,}000{,}000$$

or about 46% of occupied housing units.

Pre 1940 total housing:

$$.55(C + D + .37(G + H + J)) + .4(E + F + .63(G + H + J)) = 31{,}000{,}000$$

or about 46% of all housing units.

The three categories G, H and J (which were not broken down in the census figures as to type of tenure) have been distributed between rental and homeowner units in the same ratio as the renter/owner occupancy rates.

B.4. A Nationwide Estimate of Immediately Hazardous Housing

In constructing the EBL incidence models, NBS equated the immediately hazardous housing with 1960 "unsound" (deteriorating housing units plus dilapidated housing units), 1960 "substandard", or very crude estimates of both of these updated to 1970, primarily on the basis of total net housing change and demolition ratss. As far as a national estimate goes, one may use at this point the 6.9 million estimate of total "substandard" housing units for 1970 made by the National Commission on Urban Problems.[37] Aside from doubts as to the accuracy of the estimate, using Census "substandard" as a surrogate for "acute lead hazard" housing should not raise serious objections. Virtually all "unsound" housing is old enough to have peeling lead paint, and accessible lead paint is most likely to be found in otherwise sound houses where there are plumbing deficiences--a condition often associated with age and indifferent maintenance. To the extent that this latter is not true, for example in rural areas, it is very likely counterbalanced by older urban housing units with peeling lead paint which are nevertheless ruled sound according to the census definitions.

An estimate was also made using the 1960 unsound housing rates, under the assumption (which undoubtedly overestimates the current unsound housing stock) that these rates also apply at the SMSA level in 1970. Table 39 lists the hazardous housing units estimated in this manner for each SMSA. The total number of units for all SMSA's is 5,270,000. Since housing in SMSA's represents 68% of all housing units, this procedure leads to an estimate of 7,750,000 unsound units nationwide.

Table 39

Estimate of the Immediately Hazardous Housing in Each SMSA

SMSA	Hazardous Housing
Abilene, Tex.	8400
Akron, Ohio	22100
Albany, Ga.	6800
Albany-Schenectady-Troy, N.Y.	36100
Albuquerque, N. Mex.	9500
Allentown-Bethlehem-Easton, Pa.-N.J.	19100
Altoona, Pa.	11900
Amarillo, Tex.	7300
Anaheim-Santa Ana-Garden Grove, Cal.	15400
Anderson, Ind.	9400
Ann Arbor, Mich.	6700
Appleton-Oshkosh, Wisc.	4500
Asheville, N.C.	11500
Atlanta, Ga.	56100
Atlantic City, N.J.	8400
Augusta, Ga.	17100
Austin, Tex.	12500
Bakersfield, Cal.	20900
Baltimore, Md.	66200
Baton Rouge, La.	13400
Bay City, Mich.	6000
Beaumont-Port Arthur-Orange, Tex.	21700
Billings, Mont.	6200
Biloxi-Gulfport, Miss.	6600
Binghampton, N.Y.	9700
Birmingham, Ala.	51300
Bloomington-Normal, Ill.	7000
Boise City, Ida.	5900
Boston, Mass.	100400
Bridgeport, Conn.	11000
Bristol, Conn.	1700
Brockton, Mass.	5500
Brownsville-Harlingen-San Benito, Tex.	14800
Bryan-College Station, Tex.	3000
Buffalo, N.Y.	54900
Canton, Ohio	18200
Cedar Rapids, Iowa	6900
Champaign-Urbana, Ill.	5400
Charleston, S.C.	17200
Charleston, W. Va.	19100

Table 39 Continued

SMSA	Hazardous Housing
Charlotte, N.C.	16000
Chattanooga, Tenn.	22400
Chicago, Ill.	229600
Cincinnati, Ohio-Ky.-Ind.	51200
Cleveland, Ohio	59600
Colorado Springs, Colo.	6300
Columbia, Miss.	2500
Columbia, S.C.	15600
Columbus, Ga.	15800
Columbus, Ohio	36200
Corpus Christi, Tex.	15800
Dallas, Tex.	61000
Davenport-Rock Island-Moline, Iowa	14100
Dayton, Ohio	26200
Decatur, Ill.	6600
Denver, Colo.	33600
Des Moines, Iowa	17300
Detroit, Mich.	124900
Dubuque, Iowa	5400
Duluth-Superior, Minn.-Wis.	18800
Durham, N.C.	7200
El Paso, Tex.	16500
Erie, Pa.	12100
Eugene, Ore.	9100
Evansville, Ind.-Ky.	12900
Fall River, Mass.-R.I.	6600
Fargo-Morehead, N. Dak.-Minn.	5200
Fayetteville, N.C.	12200
Fitchburg-Leominster, Mass.	7300
Flint, Mich.	16800
Fort Lauderdale-Hollywood, Fla.	9600
Fort Smith, Ark.-Okla.	19500
Fort Wayne, Ind.	10500
Fort Worth, Tex.	32700
Fresno, Cal.	25900
Gadsden, Ala.	11500
Gainesville, Fla.	2600
Galveston-Texas City, Tex.	11700
Gary-Hammond-East Chicago, Ind.	26000
Grand Rapids, Mich.	15300
Great Falls, Mont.	6900
Green Bay, Wisc.	4800
Greensboro-Winston Salem-High Point, N.C.	25700
Greenville, S.C.	16000

Table 39 Continued

SMSA	Hazardous Housing
Hamilton-Middleton, Ohio	8300
Harrisburg, Pa.	13800
Hartford, Conn.	14400
Honolulu, Haw.	26800
Houston, Tex.	60200
Huntington-Ashland, W. Va.-Ky.-Ohio	21200
Huntsville, Ala.	7400
Indianapolis, Ind.	33600
Jackson, Mich.	7200
Jackson, Miss.	12400
Jacksonville, Fla.	29200
Jersey City, N.J.	31800
Johnstown, Pa.	21500
Kalamazoo, Mich.	7600
Kansas City, Mo.-Kan.	55000
Kenosha, Wisc.	4500
Knoxville, Tenn.	26900
La Crosse, Wisc.	3700
Lafayette, La.	7100
Lafayette-W. Lafayette, Ind.	3200
Lake Charles, La.	8900
Lancaster, Pa.	9900
Lansing, Mich.	14000
Laredo, Tex.	9700
Las Vegas, Nev.	3600
Lawrence-Haverhill, Mass.-N.H.	10700
Lawton, Okla.	5400
Lewiston-Auburn, Maine	5900
Lexington, Ky.	7900
Lima, Ohio	6300
Lincoln, Neb.	10100
Little Rock-North Little Rock, Ark.	16600
Loraine-Elyria, Ohio	7900
Los Angeles-Long Beach, Cal.	172000
Louisville, Ky.-Ind.	36600
Lowell, Mass.	7000
Lubbock, Tex.	9300
Lynchburg, Va.	8200
Macon, Ga.	16000
Madison, Wisc.	7100
Manchester, N.H.	6600
Mansfield, Ohio	3800

Table 39 Continued

SMSA	Hazardous Housing
McAllen-Pharr-Edenburg, Tex.	3200
Memphis, Tenn.-Ark.	34500
Meriden, Conn.	2500
Miami, Fla.	29300
Midland, Tex.	4100
Milwaukee, Wisc.	37200
Minneapolis-St. Paul, Minn.	52900
Mobile, Ala.	25500
Modesto, Cal.	1700
Monroe, La.	9900
Montgomery, Ala.	13700
Muncie, Ind.	6100
Muskegon-Muskegon Heights, Mich.	7800
Nashua, N.H.	2200
Nashville, Tenn.	24600
New Bedford, Mass.	6200
New Britain, Conn.	4000
New Haven, Conn.	13400
New London-Groton-Norwich, Conn.	8100
New Orleans, La.	58400
New York, N.Y.	467900
Newark, N.J.	68900
Newport News-Hampton, Va.	11500
Norfolk-Portsmouth, Va.	29400
Norwalk, Conn.	3300
Odessa, Tex.	6200
Ogden, Utah	4600
Oklahoma City, Okla	30600
Omaha, Nebr.-Iowa	22300
Orlando, Fla.	16600
Owensboro, Ky.	2900
Oxnard-Ventura, Cal.	9500
Paterson-Clifton-Passaic, N.J.	28000
Pensacola, Fla.	14600
Peoria, Ill.	14700
Petersburg-Colonial Heights, Va.	4800
Philadelphia, Pa.-N.J.	138500
Phoenix, Ariz.	32100
Pine Bluff, Ark.	12800
Pittsburgh, Pa.	125200
Pittsfield, Mass.	4200
Portland, Maine	5300

Table 39 Continued

SMSA	Hazardous Housing
Portland, Ore.-Wash.	43300
Providence-Pawtucket-Warwick, R.I.-Mass.	33200
Provo-Orem, Utah	3700
Pueblo, Colo.	8600
Racine, Wisc.	5500
Raleigh, N.C.	11600
Reading, Pa.	11800
Reno, Nev.	5000
Richmond, Va.	16900
Roanoke, Va.	7100
Rochester, Minn.	2300
Rochester, N.Y.	20300
Rockford, Ill.	9000
Sacramento, Cal.	18600
Saginaw, Mich.	9800
St. Joseph, Mo.	9700
St. Louis, Mo.-Ill.	107300
Salem, Ore.	12800
Salinas-Monterey, Cal.	1400
Salt Lake City, Utah	14200
San Angelo, Tex.	5000
San Antonio, Tex.	41700
San Bernardino-Riverside-Ontario, Cal.	38200
San Diego, Cal.	29400
San Francisco-Oakland, Cal.	84900
San Jose, Cal.	15800
Santa Barbara, Cal.	6300
Santa Rosa, Cal.	1700
Savannah, Ga.	15400
Scranton, Pa.	13700
Seattle-Everett, Wash.	50200
Shreveport, La.	22800
Sioux City, Iowa-Neb.	9300
Sioux Falls, S.D.	5200
South Bend, Ind.	9000
Spokane, Wash.	14500
Springfield, Ill.	9200
Springfield, Mo.	8300
Springfield, Ohio	7500
Springfield-Chicopee-Holyoke, Mass.-Conn.	20000
Stamford, Conn.	4400
Steubenville-Weirton, Ohio-W. Va.	11400

Table 39
Continued

SMSA	Hazardous Housing
Stockton, Cal.	14900
Syracuse, N.Y.	29800
Tacoma, Wash.	15700
Tallahassee, Fla.	6500
Tampa-St. Petersburg, Fla.	38800
Terre Haute, Ind.	9700
Texarkana, Tex.-Ark.	13900
Toledo, Ohio-Mich.	19300
Topeka, Kan.	8300
Trenton, N.J.	8700
Tucson, Ariz.	11400
Tulsa, Okla.	30000
Tuscaloosa, Ala.	9800
Tyler, Tex.	9900
Utica-Rome, N.Y.	22400
Vallejo-Napa, Cal.	10700
Vineland-Millville-Bridgeton, N.J.	2400
Waco, Tex.	11900
Washington, D.C.-Md.-Va.	44000
Waterbury, Conn.	6600
Waterloo, Iowa	6000
West Palm Beach, Fla.	12800
Wheeling, W. Va.-Ohio	15600
Wichita, Kan.	17000
Wichita Falls, Tex.	9000
Wilkes Barre-Hazleton, Pa.	17100
Wilmington, Del.-N.J.-Md.	14800
Wilmington, N.C.	10400
Worcester, Mass.	13300
York, Pa.	9600
Youngstown-Warren, Ohio	23800
Total for all SMSA's	5,267,600

Footnotes

1. [18], [28]

2. [27]

3. [18]

4. [27] and conversations with Ray Tyler, Chief of the Accident Control Division, Philadelphia Department of Public Health; Mrs. Elaine Whitmire, Coordinator of the Lead Paint Poisoning Program, New Haven, Connecticut; Dan Still, Lead Poisoning Control Bureau, New York City; and Dr. Herbert L. Slutsky, Lead Program Coordinator, Chicago Board of Health.

5. [18], [6]

6. [11], [35], [36]

7. [11]

8. [11], [43]

9. [43]

10. [16], [42]

11. [18]

12. [18]

13. [18]

14. [18]

15. "Paint Suit Lost by Blind Child", Washington Star, Friday, November 19, 1971, Section C, page 1.

16. Chapter 4 of this report documents the substantiation effort which has been possible to date; its findings, though limited in scope, can be characterized as distinctly confirmatory, rather than the opposite.

17. Throughout this report the term "data items" will be used to refer to categories of information, while "data" will refer to numbers in those categories.

18. These refer to areas reporting lead poisoning up through 1971.

19. The data available for many of these characteristics may be obtained as the number of ____ or the fraction of ____, only one of which will be listed.

20. The following U.S. Census definitions may clarify the data items listed.

Housing Categories:

Sound - Having no defects that could not be alleviated by routine maintenance procedures.

Deteriorating - Containing some serious defects: holes in wallboards several inches in diameter, some rotting in structural members, heavy splintering, etc.

Dilapidated - Severe surface damage, fractures in structural members, etc.

Unsound - Deteriorating or Dilapidated.

Dwelling Unit; Housing Unit - Living quarters for a household; primarily a house or apartment. For our purposes the terms are interchangeable. Census used "Dwelling Unit" through 1960 and "Housing Unit" with minor technical changes in the definition, thereafter.

21. In a New York sample of paints, 8 out of 76 sampled were found to have greater than 1% lead as reported in the New York Times of July 24, 1971. An intentionally biased survey directed by the National Bureau of Standards for HUD and reported to the Senate Subcommittee on Health in March of 1972 also found some interior house paints with a lead content of greater than 1%.

22. As in Table 7 this may be obtained either as the number of ____ or a fraction of ____.

23. The data available for this characteristic and the others described as "distributions" is the fraction of the persons falling in each subcategory of the characteristic.

24. Exceptions are primarily "twin-cities" located less than 20 miles apart and having a combined population of more than 50,000.

25. Rural poor in substandard housing, particularly in the South and Southwest may live in dwelling units that are unpainted or whitewashed, rather than in housing with old leaded paint. Most housing in the West and in suburban areas throughout the country is on the average of more recent vintage than that in the urban East and Midwest, and thus less likely to contain lead paint.

26. [63]

27. [65]

28. Follow-up medical records were not available to project staff.

29. [64]

30. [65]

31. Conversations with experts in Eastern cities (see footnote 4), Dr. J. Julian Chisolm of Baltimore and members of HEW's Bureau of Community and Environmental Management.

32. [27]

33. In 1970 there were 243 SMSA's, but only 189 in 1960. [61] was used to obtain 1960 data for all but 2 of the 243 1970-SMSA's. Data for these 2 could have been obtained, but with much greater difficulty.

34. Reported orally during a field trip to the New Haven Lead Poisoning Prevention Program.

35. Data in the Census of Manufacturers and the Minerals Yearbook were analyzed to calculate these figures.

36. [61]

37. [62]

Bibliography

I. Lead Poisoning Literature

1. Bachman, Gaylen D., Jacqueline M. Schwartz, and Vernon E. Weckwirth, "A Report on Lead Poisoning in Children and Youth Projects," Systems Development Project, School of Public Health, University of Minnesota, Oct. 1970.

2. Barltrop, Donald and N. J. P. Killala, "Factors Influencing Exposure of Children to Lead", Arch. Dis. Childh., Vol. 44, No. 476, Aug. 1969.

3. Bazell, Robert J., "Health Programs: Slum Children Suffer Because of Low Funding", Science, Vol. 172, May 1971.

4. Berg, J. M. and M. Zappella, "Lead Poisoning in Childhood with Particular Reference to Pica and Mental Sequelae", J. of Mental Deficiency Research, Vol. 8, June 1964.

5. Byers, R. K., "Lead Poisoning Review of the Literature and Report on 45 Cases", Pediatrics, Vol. 23, March 1959.

6. Challop, Roger, "Lead Poisoning in Children - National Evaluation Proposal", HEW, April 1971.

7. Chisolm, J. Julian, "Childhood Lead Intoxification: A Preventable Summertime Disease", Pediatrics Digest, Vol. 6. July 1964.

8. Chisolm, J. Julian, "Lead Poisoning", Scientific American, Vol. 224, No. 2, Feb. 1971.

9. Chisolm, J. Julian, "Treatment of Lead Poisoning", Modern Treatment, Vol. 4, July 1967.

10. Chisolm, J. Julian, "The Use of Chelating Agents in the Treatment of Acute and Chronic Lead Intoxification in Childhood", J. of Pediatrics, Vol. 73, No. 1, July 1968.

11. Chisolm, J. Julian and Harold E. Harrison, "The Exposure of Children to Lead", J. of Pediatrics, Vol. 18, Dec. 1956.

12. Chisolm, J. Julian and Eugene Kaplan, "Lead Poisoning in Childhood-Comprehensive Management and Prevention", J. of Pediatrics, Vol. 73, No. 6, Dec. 1968.

13. Christian, Joseph R., Bohdan S. Celewyez and Samuel L. Andelman, "A Three-Year Study of Lead Poisoning in Chicago", AJPH, Vol. 54, No. 8, Aug. 1964.

14. Clark, Alan J. and George W. Hallett, "Lead Poisoning Survey--Portland, Maine", J. of Maine Medical Association, Vol. 62, Jan. 1971.

15. Cohen, George J. and Walter E. Ahrens, "Chronic Lead Poisoning", J. of Pediatrics, Vol. 54, No. 3, March 1954.

16. Cohen, George J., Reginald S. Lourie, and William Abernethy, "Grand Rounds: Pica and Lead Poisoning", Clinical Proceedings Children's Hospital of the District of Columbia, Vol. XXI, Nos. 7 and 8, July-Aug. 1965.

17. Conn, Robert H. and Dudley Anderson, "D.C. Mounts Unfunded Program of Screening for Lead Poisoning", HSMHA Health Reports, Vol. 86, No. 5, May 1971.

18. "Control of Lead Poisoning in Children", HEW, PHS, BCEM, Dec. 1970.

19. Deeths, Tony M. and James T. Breeden, "Poisoning in Children--A Statistical Study of 1057 Cases", J. of Pediatrics, Vol. 78, No. 2, Feb. 1971.

20. "Facts About Lead and Pediatrics", Lead Industries Association Inc.

21. Freeman, Ronald, "Chronic Lead Poisoning in Children Diagnosed in Sidney, 1948-1967", The Medical Journal of Australia, March 1970.

22. Fine, Philip R., "A Lead Poisoning Surveillance Program Proposal", Division of Disease Control, Illinois Department of Public Health, May 1971.

23. Fisher, Martha, "Lead Poisoning in Children", Journal of Housing, Vol. 6, 1970.

24. Greengard, Joseph, "Lead Poisoning in Childhood: Signs, Symptoms, Current Therapy, Clinical Expressions", Clinical Pediatrics, Vol. 5, No. 5, May 1966.

25. Griggs, Robert C., Irving Sunshine, Vaun A. Newill, Burritt W. Newman, Stuart Buchanan and Cleo A. Rasch, "Environmental Factors in Childhood Lead Poisoning", J. of the AMA, Vol. 187, No. 10, March 1964.

26. Guinee, Vincent F., "Lead Poisoning in New York City", paper presented at New York Academy of Sciences, Dec. 1970.

27. Guinee, Vincent F., "The Position of New York City on the Level of Appropriations for Control of Childhood Lead Paint Poisoning", papers submitted to the Sub-committee on Labor and Public Welfare of the Senate Committee on Appropriations, July 1970 and July 1971.

28. "Hearing Before the Subcommittee on Health of the Committee on Labor and Public Welfare, U.S. Senate, Ninety-first Congress", Nov. 1970.

29. "Hearings Before the Subcommittee on Housing of the Committee on Banking and Currency", House of Representatives, Ninety-first Congress, July 1970.

30. Ingalls, Theodore H., Emil A. Tiboni, and Milton Werrin, "Lead Poisoning in Philadelphia 1955-1960", Archives of Environmental Health, Vol. 3, Nov. 1961.

31. Jacobziner, Harold, "Lead Poisoning in Childhood: Epidemiology, Manifestations, and Prevention", Clinical Pediatrics, Vol. 5, No. 5, May 1966.

32. Jacobziner, Harold and Harry W. Raybin, "The Epidemiology of Lead Poisoning in Children", Archives of Pediatrics, Feb. 1962.

33. Jacobziner, Harold and Harry W. Raybin, "Lead Poisoning in Young Children - Fatal and Nonfatal", N. Y. State J. of Med., Jan. 1960.

34. Jenkins, C. David and Robert B. Mellins, "Lead Poisoning in Children--A Study of Forty-six Cases", AMA Archives of Neurology and Psychiatry, Jan. 1957.

35. Kehoe, Robert A., "The Metabolism of Lead in Man in Health and Disease", J. of the Royal Institute of Public Health and Hygiene, 1961.

36. Kehoe, Robert A., "Normal Metabolism of Lead", Archives of Environmental Health, Vol. 8, Feb. 1964.

37. Lead Paint and Other Special Labelling, American Standard Specifications to Minimize Hazards to Children from Residual Surface Coating Materials.

38. "Lead Poisoning in Children: Diagnostic Criteria", HEW, May 1959.

39. "Lead Poisoning in Children from Paint", BCEM, Aug. 1969.

40. Lin-Fu, Jane, "Childhood Lead Poisoning", Children, Vol. 17, No. 1, Jan.-Feb. 1970.

41. Lin-Fu, Jane, "Lead Poisoning in Children", HEW Children's Bureau Publication No. 452-1967, 1967.

42. Lourie, Reginald S., Emma M. Layman, and Frances K. Millican, "Why Children Eat Things that are Not Food", Children, Vol. 10, No. 4, July-Aug. 1963.

43. Lutz, Garson A., Arthur A. Levin, Sanford G. Bloom, Kaj L. Nielsen, Jack L. Cross, and David L. Morrison, "Technical, Intelligence, and Project Information System for the Environmental Health Service, Volume III", Lead Model Case Study, Battelle Memorial Institute, June 1970.

44. McLaughlin, Mary, "Two Health Problems--One Solution", Bull. N. Y. Acad. Med., Vol. 46, No. 6, June 1970.

45. "Medical Aspects of Childhood Lead Poisoning", HSMHA Health Reports, Vol. 86, No. 2, Feb. 1971.

46. Meigs, J. Wister and Elaine Whitmire, "Epidemiology of Lead Poisoning in New Haven Children--Operational Factors", Connecticut Medicine, Vol. 35, No. 6, June 1971.

47. Mellins, Robert B. and C. David Jenkins, "Epidemiological and Psychological Study of Lead Poisoning in Children", J. of AMA, Vol. 158, No. 1, May 1955.

48. Mushkin, Selma J. and Ralph Freidin, "Lead Poisoning in Children: The Problem in D.C. and Preventive Steps", Public Services Laboratory, Georgetown University, September 1971.

49. Oberle, Mark W., "Lead Poisoning: A Preventable Childhood Disease of the Slums", Science, Vol. 165, Sep. 1969.

50. Public Law 91-695, Ninety-first Congress, H. R. 19172, Jan. 13, 1972.

51. Rait, J. R. and C. Teng, "Lead Poisoning Issue Study", New York City Rand Institute, Feb. 1970.

52. "Report of Governor's Task Force on Lead Poisoning", State of Connecticut, Dec. 1970.

53. Sachs, Henrietta K., Larry A. Blanksma, Edward F. Murray, and Morgan J. O'Connell, "Ambulatory Treatment of Lead Poisoning, Report of 1155 Cases", Pediatrics, Vol. 46, No. 3, Sep. 1970.

54. Schucker, George W., Edward H. Vail, Elizabeth B. Kelly, and Emanuel Kaplan, "Prevention of Lead Paint Poisoning Among Baltimore Children", Public Health Reports, Vol. 80, No. 11, Nov. 1965.

55. Smith, Hugo Dunlap, "Pediatric Lead Poisoning", Archives of Environmental Health, Vol. 8, Feb. 1964.

56. "The Surgeon General's Policy Statement on Medical Aspects of Childhood Lead Poisoning", Nov. 1970.

57. "Symposium on Environmental Lead Contamination", Public Health Service Publication No. 1440, March 1966.

58. Tiboni, Emil A., "Control of Childhood Lead Poisoning", Public Health Reports, Vol. 79, No. 2, Feb. 1964.

59. Tyler, Raymond L., "Philadelphia Combats 'Silent Epidemic' in the Ghetto", J. of Environmental Health, Vol. 33, No. 1, July-Aug. 1970.

60. Williams, Huntington, Emanuel Kaplan, Charles E. Couchman and R. R. Sayers, "Lead Poisoning in Young Children", Public Health Reports, Vol. 67, No. 3, March 1952.

II. Demographic Data

61. *City and County Data Book 1967*, U. S. Department of Commerce, Bureau of the Census.

62. Kristoff, F. S., *Urban Housing Needs Through the 1980's: An Analysis and Projection*, Report Number 10, The National Commission on Urban Problems, Washington, D.C., 1968.

III. Statistical Analysis

63. Mood, Alexander M., and Franklin A, Graybill, *Introduction to the Theory of Statistics*, McGraw-Hill, New York, 1963.

64. Natrella, Mary Gibbons, *Experimental Statistics*, National Bureau of Standards Handbook 91, 1966.

65. Siegel, Sidney, *Nonparametric Statistics for the Behavioral Sciences*, McGraw-Hill, New York, 1956.

FORM NBS-114A (1-71)

U.S. DEPT. OF COMM. BIBLIOGRAPHIC DATA SHEET	1. PUBLICATION OR REPORT NO. NBS TN-746	2. Gov't Accession No.	3. Recipient's Accession No.

4. TITLE AND SUBTITLE

Estimates of the Nature and Extent of Lead Paint Poisoning in the United States

5. Publication Date December 1972

6. Performing Organization Code

7. AUTHOR(S) Judith F. Gilsinn

8. Performing Organization

9. PERFORMING ORGANIZATION NAME AND ADDRESS

NATIONAL BUREAU OF STANDARDS
DEPARTMENT OF COMMERCE
WASHINGTON, D.C. 20234

10. Project/Task/Work Unit No. 4314518

11. Contract/Grant No.

12. Sponsoring Organization Name and Address

Department of Housing and Urban Development

13. Type of Report & Period Covered Final

14. Sponsoring Agency Code

15. SUPPLEMENTARY NOTES

16. ABSTRACT (A 200-word or less factual summary of most significant information. If document includes a significant bibliography or literature survey, mention it here.)

This report evaluates the nationwide magnitude and extent of pediatric lead poisoning resulting from the ingestion of lead-based paint. Estimates are given of the number of children who have elevated blood lead levels (40 μg or more of lead per 100 ml of whole blood) in each of 241 Standard Metropolitan Statistical Areas throughout the country. The mathematical models used to obtain these estimates are documented together with the assumptions and data upon which those models are based. Partial validation of both models and assumptions is also reported.

17. KEY WORDS (Alphabetical order, separated by semicolons) Childhood diseases; estimation; health problems; lead; lead paint; lead paint poisoning; lead poisoning; mathematical modeling; models; urban health problems.

18. AVAILABILITY STATEMENT

☒ UNLIMITED.

☐ FOR OFFICIAL DISTRIBUTION. DO NOT RELEASE TO NTIS.

19. SECURITY CLASS (THIS REPORT) UNCLASSIFIED

20. SECURITY CLASS (THIS PAGE) UNCLASSIFIED

21. NO. OF PAGES 163

22. Price $2.00

USCOMM-DC 66244-P71

NBS TECHNICAL PUBLICATIONS

PERIODICALS

JOURNAL OF RESEARCH reports National Bureau of Standards research and development in physics, mathematics, and chemistry. Comprehensive scientific papers give complete details of the work, including laboratory data, experimental procedures, and theoretical and mathematical analyses. Illustrated with photographs, drawings, and charts. Includes listings of other NBS papers as issued.

Published in two sections, available separately:

- **Physics and Chemistry**

Papers of interest primarily to scientists working in these fields. This section covers a broad range of physical and chemical research, with major emphasis on standards of physical measurement, fundamental constants, and properties of matter. Issued six times a year. Annual subscription: Domestic, $9.50; $2.25 additional for foreign mailing.

- **Mathematical Sciences**

Studies and compilations designed mainly for the mathematician and theoretical physicist. Topics in mathematical statistics, theory of experiment design, numerical analysis, theoretical physics and chemistry, logical design and programming of computers and computer systems. Short numerical tables. Issued quarterly. Annual subscription: Domestic, $5.00; $1.25 additional for foreign mailing.

TECHNICAL NEWS BULLETIN

The best single source of information concerning the Bureau's measurement, research, developmental, cooperative, and publication activities, this monthly publication is designed for the industry-oriented individual whose daily work involves intimate contact with science and technology—*for engineers, chemists, physicists, research managers, product-development managers, and company executives.* Includes listing of all NBS papers as issued. Annual subscription: Domestic, $3.00; $1.00 additional for foreign mailing.

Bibliographic Subscription Services

The following current-awareness and literature-survey bibliographies are issued periodically by the Bureau: Cryogenic Data Center Current Awareness Service (weekly), Liquefied Natural Gas (quarterly), Superconducting Devices and Materials (quarterly), and Electromagnetic Metrology Current Awareness Service (monthly). Available only from NBS Boulder Laboratories. Ordering and cost information may be obtained from the Program Information Office, National Bureau of Standards, Boulder, Colorado 80302.

NONPERIODICALS

Applied Mathematics Series. Mathematical tables, manuals, and studies.

Building Science Series. Research results, test methods, and performance criteria of building materials, components, systems, and structures.

Handbooks. Recommended codes of engineering and industrial practice (including safety codes) developed in cooperation with interested industries, professional organizations, and regulatory bodies.

Special Publications. Proceedings of NBS conferences, bibliographies, annual reports, wall charts, pamphlets, etc.

Monographs. Major contributions to the technical literature on various subjects related to the Bureau's scientific and technical activities.

National Standard Reference Data Series. NSRDS provides quantitative data on the physical and chemical properties of materials, compiled from the world's literature and critically evaluated.

Product Standards. Provide requirements for sizes, types, quality, and methods for testing various industrial products. These standards are developed cooperatively with interested Government and industry groups and provide the basis for common understanding of product characteristics for both buyers and sellers. Their use is voluntary.

Technical Notes. This series consists of communications and reports (covering both other-agency and NBS-sponsored work) of limited or transitory interest.

Federal Information Processing Standards Publications. This series is the official publication within the Federal Government for information on standards adopted and promulgated under the Public Law 89–306, and Bureau of the Budget Circular A–86 entitled, Standardization of Data Elements and Codes in Data Systems.

Consumer Information Series. Practical information, based on NBS research and experience, covering areas of interest to the consumer. Easily understandable language and illustrations provide useful background knowledge for shopping in today's technological marketplace.

CATALOGS OF NBS PUBLICATIONS

NBS Special Publication 305, Publications of the NBS. 1966-1967. When ordering, include Catalog No. C13.10:305. Price $2.00; 50 cents additional for foreign mailing.

NBS Special Publication 305, Supplement 1, Publications of the NBS, 1968-1969. When ordering, include Catalog No. C13.10:305/Suppl. 1. Price $4.50; $1.25 additional for foreign mailing.

NBS Special Publication 305, Supplement 2, Publications of the NBS, 1970. When ordering, include Catalog No. C13.10:305/Suppl. 2. Price $3.25; 85 cents additional for foreign mailing.

Order NBS publications (except Bibliographic Subscription Services) from: Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

U.S. DEPARTMENT OF COMMERCE
National Bureau of Standards
Washington, D.C. 20234

OFFICIAL BUSINESS

Penalty for Private Use, $300

POSTAGE AND FEES PAID
U.S. DEPARTMENT OF COMMERCE
215

U.S.MAIL