Safe Yards: Improving Urban Health through Lead-Safe Yards

Jill S. Litt, H. Patricia Hynes, Paul Carroll, Robert Maxfield, Pat McLaine, and Carol Kawecki

CHILDHOOD lead poisoning is one example of a contemporary environmental health problem that has been treated and managed through an array of environmental and biomedical l interventions and prevention strategies. It is an issue that has been a concern of public health officials for decades and has been addressed quite successfully from a national perspective. By eliminating two major sources of exposures—leaded gasoline and leaded paint—blood lead levels for the majority of Americans have dropped dramatically over the past two decades.

Unfortunately, for those who live in poorly maintained housing in older urban neighborhoods, environmental lead continues to pose health threats, particularly for those under the age of six. The threats of lead poisoning are most prevalent in poor, minority, and immigrant communities and are compounded by additional environmental hazards including indoor air contaminants (e.g., allergens, combustion by-products, volatile organic compounds, pesticides) and neighborhood factors such as deteriorating infrastructure, housing demolition, abandoned housing, congested roadways, violence, industrial land uses, and vacant land. These environmental hazards are signals of compromised neighborhoods and are linked to declines in community health.

Center for Disease Control and Prevention

Fullilove et al.

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The complexities of inner-city lead poisoning and the significance of this issue to millions of affected children and their families continue to motivate tens of thousands of public officials, medical providers, environmental scientists, engineers, lawyers, and policy makers in managing lead exposures and preventing adverse health effects. One new focus of national and local lead poisoning prevention efforts is the residential yard in older urban neighborhoods.

From 1998 to 2001, a collaboration of government, university, and community partners conducted a three-phase lead-safe yard intervention pilot project in Boston. The Boston Lead-Safe Yard Project was funded by the U.S. Environmental Protection Agency's (EPA) Environmental Monitoring for Public Access and Community Tracking (EMPACT) program. Its goal was to generate real-time data on lead in urban soil that would enable us to design and implement a community-based program to reduce exposure to soil lead in residential yards of two Boston neighborhoods, Roxbury and Dorchester. The project components included: outreach to and education of homeowners and residents; soil analysis to establish baseline lead levels in soil; development and application of cost-effective landscape measures to reduce exposure to high lead soil; communication with homeowners about design decisions and long-term maintenance; and dissemination of the project methods to community agencies, local government, and cities in other regions for replication.

A previous publication presented the initial project planning, yard selection criteria, the risk-reducing landscape techniques used in the intervention, and lead soil data from the first two phases of this three-phase project. In addition, a project handbook was developed, as the project was concluding its final phase, to provide detailed instructions for community and public agencies on how to organize and implement a Lead-Safe Yard program. The project handbook contains sample consent forms, sample yard plans color-coded by lead levels and yard uses, construction details and specifications for landscape measures, and cost estimates of materials and labor.

Hynes et al.

USEPA, *Lead-Safe Yards...*

This paper has two interrelated purposes. First, it will contextualize the Lead-Safe Yard project within the current arena of environmental health policy. Second, it will present the descriptive soil lead data from all three phases of the project in order to: 1) establish a baseline profile of soil lead for Boston inner-city yards, and 2) compare the baseline and average levels found in yards with current regulatory levels for lead in residential soil.

Part I defines environmental health in its fullest sense, describes the changing boundaries of environmental health, lists recent developments in community-based environmental health, and outlines the

changing face of public sector agencies in their support of localized environmental health research and practice. Part II provides background information on lead poisoning trends in the United States and policy guidelines. Part III describes and discusses the methods and results from the soil lead analysis and intervention in residential yards. The concluding section includes a preliminary discussion of the project evaluation process as well as possible next steps.

The Urban Setting and Environmental Health

Understanding, harmonizing, and sustaining the relationships between the environment and public health requires a broadening of "environment health" as a concept and its respective theoretical underpinnings, research protocols, and practice strategies. While the current environmental health paradigm, which reflects the continuum from source of contaminant to environmentally-related health outcome, is useful in looking at the relationships between individual substances, individual pathways of exposure, and individual health risks, it falls short of providing a useful framework to consider other non-chemical environmental factors and the interaction of multiple environmental factors in shaping a population's health. Such factors include, physical and biological hazards, severely diminished natural resources, deteriorating infrastructure and blight, and housing and school quality. For the purposes of this paper, we have adopted the following definition of environmental health to provide a broader context when considering lead poisoning in urban communities and environmental interventions, such as the EMPACT Lead-SafeYard project:

> Environmental health includes "those aspects of human health, including quality of life, that are determined by interactions with physical, chemical, biological, and social factors in the environment. It also refers to the theory and practices of assessing, correcting, controlling, and preventing those factors in the environment that may adversely affect the health of present and future generations." **(PAGE NUMBER??)**

Goldman et al.

Changing Times

Together, the toxics movement of the late 1980s, the environmental and social justice movements of the 1980s and 1990s, and the regulatory reform efforts of the 1990s have been instrumental in identifying the shortcomings of existing regulations, expanding the scope of environmental health, and forcing innovations in related

research, policy making, and practice. As this sea change has liberated some institutional, financial, and political resources, scientists and policy makers have been able to pursue and investigate the multifaceted aspects of environmental health by developing and employing more systematic approaches that capture cumulative environmental risk, the complicated nature of the built environment and its role in community health, and community priorities and concerns. Importantly, such approaches advocate and require, in some cases, that research and implementation strategies address "pollution" together with "poverty" to ultimately improve and sustain community health and well-being.

Paradigmatic shifts in environmental health have been embraced by community researchers, practitioners, and affected communities, who recognize the need for more holistic, bottom-up approaches to community development, local environmental management, and public health protection. One approach that befits this new direction in environmental health is "assets-based community development (ABCD)", an approach that is assets-oriented rather than deficiency-oriented and needs driven. ABCD spotlights community strengths by focusing on what is present in a community, including local resources, bolstering ties among residents, associations, and institutions—in essence, it is a development approach that attempts to "build from the ground up." Moreover, an assets-based approach recognizes the fundamental building blocks of a community—social capital (e.g., neighborhood cohesion), human capital (e.g., competencies and skills), physical capital (e.g., infrastructure), and natural capital (e.g., natural resources and living systems), as critical to improving health and well-being in communities.

Kretzmann et al.

Ambler
Boyce and Pastor

Within public health, community-based approaches premised on community assets have emerged in response to calls for more comprehensive and integrated approaches to research and practice solutions that affect change at the neighborhood level. The "Healthy Cities" and "Healthy People" initiatives throughout the United States and elsewhere are two efforts that have renewed recognition of the local authority as the front-line defense in public health and argue for the return of public health decision making to the local and community level.

Chaskin
Institute of Medicine2001
Israel et al.

International Healthy Cities Foundation
van Oers

From Theory to Action

The call for locally based environmental health action has been met with a surge of interest in and allocation of resources to support community-based research and activities. Various government committees and commissions, non-profit organizations, and religious organizations have endorsed or argued for such considerations in-

cluding the Institute of Medicine, U.S. Department of Health and Human Services, the U. S. Environmental Protection Agency, the Presidential/Congressional Commission on Risk Assessment and Risk Management, and the United Nations Development Program.

Ambler
Institute of Medicine 1999
Institute of Medicine 1988
US Department of Health and Human Services
National Research Council
Presidential/Congressional Commission on Risk Assessment and Risk Management, *Framework...*
Presidential/Congressional Commission on Risk Assessment and Risk Management, *Risk Assessment...*

The EPA EMPACT Program

The U.S. Environmental Protection Agency's Environmental Monitoring for Public Access and Community Tracking (EMPACT) program, which was designed to work with communities to collect, manage, and present environmental information to the public, is one example of a federally funded initiative that is community-based and assets-oriented. The EMPACT program, which organizationally resided in EPA's Office of Environmental Information, aimed to transfer timely environmental information and technological innovations to communities in order to inform local environmental decision making. Moreover, the program offered financial resources to build capacity at the community level to tackle and respond to vexing issues such as air pollution, hazardous waste management, water quality, and community exposures to toxic substances.*

USEPA *What is EMPACT?*

USEPA *Lead-Safe Yards...*

*Community capacity is the "interaction of human capital, organizational resources, and social capital existing within a given community that can be leveraged to solve collective problems and improve or maintain the well-being of a given community. It may operate through the informal social processes and/or organized effort" (Chaskin)

Lead in Soil as an Urban Environmental Hazard

Lead as a human toxicant is widely recognized to cause deleterious effects in children and adults, including developmental delays, learning disabilities, behavioral disorders, and depression. Technological improvements and advancements in epidemiologic methods continue to elucidate the clinical and sub-clinical effects of lead poisoning. Lead's persistence in the environment, its widespread use in industry, its presence in older homes, and its remnants in soil from leaded gasoline and deteriorating exterior paint on aging homes make it a public health threat in aging urban neighborhoods.

Lanphear et al. 2000

From a national perspective, federal policies and regulations that recommended or mandated the removal of lead from food cans and gasoline, respectively, have contributed to reductions in baseline blood lead levels, from 77.8 percent of the population with blood lead levels (BLLs) greater than or equal to 10 µg/dl in the late 1970s to 4.4 percent in the early 1990s.*

Mielke et al. 1983
Mielke et al. 1998

Additionally, national standards have been set to guide states and localities in their efforts to stabilize domestic interior and exterior lead levels. The implementation of local programs to achieve these standards and eliminate or prevent lead exposures varies depending

"Update: Blood Lead Levels..." Mahaffey et al
*Current action levels for lead poisoning, as set by the Centers for Disease Control and Prevention, is 10µg/dl of blood. Recent studies by Lanphear and others have shown that lead causes cognitive deficits in children at levels as low as 5 µg/dl of blood. (Lanphear 2000)

on the local "lead-scape." Low-income and minority families, those living in older housing, those living in older urban areas, and those living near point sources (e.g., lead smelters) and major roadways still suffer from excess exposures to lead in the environment. Specifically, nearly one million children are estimated to have blood lead levels (BLLs) greater than 10µg/dl and millions more are estimated to have BLLs in the range of 2.5 to 10 µg/dl.

Asante-Duah

Pirkle et al.

The intervention strategy for reducing and preventing lead exposure should reflect risk factors specific to the affected community. Historically, risk factors have included lead paint, lead pipes, and interior dust. Specialized interventions to control and prevent lead poisoning include clinical interventions such as oral chelating agents for moderately lead poisoned children, nutritional guidance, and environmental interventions including abatement of house dust and lead-based paint, and restoration or replacement of aging housing infrastructures (e.g., windows). Urban soil, on the other hand, is a significant sink of bioavailable lead (lead that can be absorbed by the body) that has not, until recently, been regulated or included in any comprehensive prevention strategy. In December 2000, the EPA promulgated standards for residential lead-contaminated bare soil that took effect March 2001. In addition to revising hazard standards for lead in house dust and paint (interior environment), it established two hazard standards for lead in soil—400 parts per million (ppm) for bare soil in play areas and 1,200 ppm average for bare soil in the rest of the yard.

"Identification of Dangerous ..."

In 1993, the EPA published the Integrated Report of the Urban Soil Lead Abatement Demonstration Project, which synthesized the findings from scientific studies carried out in three cities: Boston, Baltimore, and Cincinnati. The aims of the studies were to determine whether lead in soil was an important pathway of exposure for children and whether soil abatement was an effective measure in reducing blood lead levels. Based on these studies, the EPA concluded that when soil is a significant source of lead in a child's environment, the abatement of that soil will result in a reduced exposure and consequently a reduction in blood lead levels. From these studies, the EPA identified four major factors that would mediate the effectiveness of a soil-based intervention: 1) past history of childhood exposure to lead, 2) a direct exposure pathway between soil and the child, 3) magnitude of other sources of lead exposure, and 4) magnitude of reduction in soil-lead concentrations.

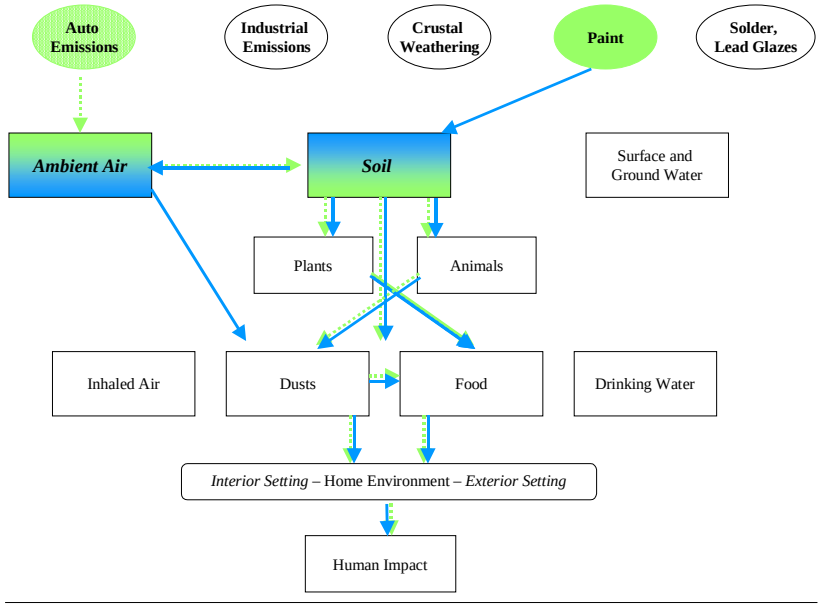
USEPA Integrted Report of the Urban Soil...
USEPA Lead-Safe Yards...

In the Boston pilot study, investigators found that lead in soil was a significant pathway for population exposures. The large inventory of older wood-framed housing (generally sided with wooden

Weitzman et al.
Aschengrau
????????

clapboard), which is likely to have exterior lead-based paint, was found to be a major source of lead in soil. Heavily traveled roadways also were recognized as potential contributors to high lead concentrations in soil from historic uses of leaded gasoline. Figure 1 illustrates the major pathways of soil-lead exposures.

FIGURE 1
Major Pathways of Soil-Lead Exposure



Source: EPA 747-R-97-006 **(NOT LISTED IN BIBLIOGRAPHY)**

In studying the impact of exterior and interior lead abatement on children's blood lead levels, the Boston research team found that a soil lead reduction of 2060 ppm was associated with a 2.25 to 2.70 mg/dl decline in blood lead levels. These results are supported by other research that has estimated that interior house dust is comprised of anywhere from 30 to 50 percent of soil dust. Given the recent findings by Lanphear and others that blood lead concentrations at levels down to 5 µg/dl are associated with deficits in children's cognitive skills, a soil lead hazard reduction program could prove to be very important for young children at risk for lead exposure.

Aschengrau

Calabrese et al.
Fergusson et al.
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Lanphear et al. 2000

Boston Lead-Safe Yard Initiative

The Lead-Safe Yard Project in Boston, Massachusetts, which was funded by the EMPACT program for three phases from 1998 through 2001, was developed to quantify lead levels in residential soil, reduce

exposure to lead-contaminated areas through low-cost landscaping interventions, and develop educational and instructional materials for reducing exposure to soil-lead in at-risk urban neighborhoods. Moreover, the study aimed to answer the following questions:

- What are average lead concentrations for residential yards in an urban area like Boston that result from multiple sources of contamination, in particular leaded gasoline and exterior lead-based paint?
- Is there a relationship between the distance from a building and soil lead concentrations in residential yards?

The intervention project was designed in response to the findings from EPA's Urban Soil Lead Abatement Demonstration project in Boston, Massachusetts (as discussed above) that found associations between soil treatment to reduce exposures in residential yards and reductions in blood lead levels in children.

The project involved a range of partners including local community organizations, the residents of affected communities, local businesses, a university, and federal and city environmental protection, public health, and housing agencies. The primary partners included the EPA New England Regional Laboratory, the Boston University School of Public Health, the Bowdoin Street Community Health Center, the Dudley Street Neighborhood Initiative, and local landscape contractors. The project widened the partnership to include Boston's Childhood Lead Poisoning Prevention Program, Lead-Safe Boston, and the National Center for Healthy Housing (NCHH) in its last phase. This partnership enabled the Lead-Safe Yard project to move the project from a pilot program to the possibility of an institutionalized program within municipal health and housing agencies, to improve the specifications and protocols, and to participate in an evaluation of the lead-safe yard intervention directed by the NCHH.

The Lead-Safe Yard Project offers an example of the translation of scientific results to sound public health practice. Additionally, it is a model that can: 1) serve as a catalyst for other neighborhood interventions and citywide initiatives, 2) restore neighborhood assets, and 3) return pride to disenfranchised communities—all essential ingredients to improving community health. The methods and results of this intervention to control lead exposures in the residential setting are described in the following section.

Methods

Community-Based Methods. We employed community-based methods in many aspects of the intervention project. The principles of

community-based research include a receptivity toward the knowledge of community partners, sharing of skills and knowledge with community partners, fair compensation to community members for work done on the project, data gathering for the purpose of education, action, and social change, and sharing of results with community participants.

Israel et al.

Neighborhood Selection Criteria. The EMPACT Lead-Safe Yard Project included two neighborhoods—Bowdoin Street (North Dorchester) and Dudley Street (Roxbury). The Bowdoin Street neighborhood was selected based on the following criteria:

Hynes et al.

- prevalence of lead poisoning
- concentration of pre-1978 painted housing (generally wooden clapboard siding)
- low-income/immigrant population
  contiguous yards (to improve potential for neighborhood-wide impact)
- presence of health organization focused on community environmental health issues
- established neighborhood environmental activities upon which the EMPACT project could build.

In the Dudley Street area, we added the criterion that eligible homes had to be certified as de-leaded in order to promote a holistic model of lead-safe homes that included the house and yard. Phase III of the EMPACT project was extended to include properties from two "spin-off" lead-safe yard programs initiated by the Lead-Safe Boston program within the Boston Department of Neighborhood Development (BDND) and the Boston Public Health Commission's Office of Environmental Health (OEH), which were based on the EMPACT prototype. The latter programs worked closely with the EPA initiative to ensure consistency in research methods, intervention approaches, and documentation and will be included in the project evaluation by NCHH.

Outreach and Education. Outreach and education were essential components of the EMPACT project. During the first phase of outreach and education, outreach staff from community organization partners provided homeowners with information about the hazards of lead in soil and invited them to participate in the project. Outreach strategies to reach homeowners included mailings, phone calls, door-to-door solicitations, and distribution of lead-safe yard literature at

community events. Education materials initially included multicultural printed handouts; later we added a video produced by the Boston Childhood Lead Poisoning Prevention Program and a quiz that tested parents' knowledge about lead poisoning. Once participants agreed to enroll in the project, outreach staff conducted the education session and coordinated the soil analysis with other members of the team. Homeowners were briefed throughout the process about the findings from the on-site soil analysis in their yard, the development of a treatment plan, and long-term maintenance of the yard intervention.

Sampling Technology and Data Collection. Soil samples were analyzed *in situ* with a Niton model 702 field portable X-ray fluorescence (FPXRF) analyzer according to procedures outlined in EPA Method 6200. The depth of *in-situ* measurements was approximately two to three millimeters and sample results were obtained within 30-60 seconds. Clark et al. have demonstrated that the FPXRF is an effective method to gather "real-time" data on lead and other metals in soil environments. Quality assurance and quality control (QA/QC) for the FPXRF analysis included calibration checks, replicate sample analyses, and confirmation sampling.*

EPA *Test Methods for Evaluating...*

Clark et al.

EPA New England Regional Laboratory

*QA/QC results from Phase I, II, and III of this project can be obtained from Mr. Paul Carroll of the U.S. Environmental Protection Agency, New England Regional Laboratory.

We evaluated four types of areas of interest in each yard during the on-site soil analysis: (1) the house drip line area (three-foot wide perimeter of a house), (2) areas of unique use, such as children's play areas and picnic and gardening areas, (3) areas of bare soil and high foot traffic, and (4) "other" areas noted by the sampling team that could present a source of lead contamination to the subject property other than the house. Examples of "other" areas included soil near painted perimeter fences, painted tool sheds and other non-residential buildings, auto repair sites, and so on.

The number of samples in the sampling plan depended on the size and shape of the yard areas of interest. A line pattern was used for linear sampling sites (e.g., house drip line). Soil measurements were taken at approximately five-foot intervals along the line. A large X was transcribed over other areas of concern, such as children's play areas. Soil measurements were taken at regular intervals along each line of the X unless the field technician determined that additional resolution was needed because of anomalous readings or suspected sources of lead contamination other than residential house paint.

FPXRF readings and descriptive information about each site, including the distance of the sample site from the house structure, housing characteristics, and weather, were recorded on a site sheet. Each data point collected during on-site sampling was considered a sub-sample and averaged with others in the area of interest (e.g., west

drip line) to determine the mean value for that area. Composite results of the soil analysis were transcribed onto a color-coded plot plan of the property for use in the exposure-reduction landscape design. Color codes were used on the property map to indicate the nature and extent of lead contamination in each area sampled and to delineate particular yard uses of concern, such as play and gardening areas.

Exposure-Reduction Measures. Once baseline data for each yard were collected and mapped onto the plot plans, landscaping teams were contracted to carry out the residential yard treatment. A coordinator for each landscaping team first met with the homeowner(s) to review the pattern of lead in the soil with the homeowner, to discuss yard treatment strategies with the homeowner, and to design a treatment plan. Engaging the homeowner in understanding the pattern of lead soil contamination and in choosing the components of the lead-safe yard landscape options was central to the project's goal of informing residents about their residential environment and including them as decision makers in the environmental improvement of their homes.

The project developed a suite of yard treatment options that reduced the risk of human exposure, that were affordable and replicable by community organizations, and that could be maintained by homeowners. The yard treatments included wood-framed drip-line boxes, newly planted grass and shrubs, stone walkways and modifications to the resident's yard use patterns (for example, relocating and constructing a child's play area or a vegetable garden in a safer part of the yard). By year three of the project, the construction specifications were fully standardized and priced, thus improving the reliability and durability of the exposure-reduction work. When the yard treatments were completed, the property owner was given a maintenance manual with instructions on maintaining the treatments. (See Hynes et al. and EPA, *Lead-Safe Yards* for more detailed explanations of treatment measures and samples of yard plans and specifications, materials used, costs, and maintenance manuals and contracts).

Data Analysis. Lead sample data were analyzed using SAS 8.0®. The "yard" rather than the individual soil sample is the primary unit of analysis. Aggregating data at the yard level reduces the variability introduced into the sub-yard results because of over-sampling in areas, such as near wooden garages and fences, that warranted further investigation.

The concentration of soil-lead in the yard is plotted at regular intervals (0-3 feet, 3-8 feet, 8-12 feet, 12 to 16 feet, and > 16 feet) in

order to illustrate the distribution of soil lead with distance from the house. Results are reported by geometric mean, arithmetic mean, and range. The geometric mean, like the median, is an appropriate metric since it is less sensitive to outliers and thus provides a better statistical profile of lead in soil trends in an urbanized area. On the other hand, outliers, which may be a result of common urban sources such as paint chips, waste burning, or auto repair, are important because they represent "hot spots" of potential residential exposure. Thus, we also report lead levels using the arithmetic mean and range.

To estimate the urban geochemical baseline for lead in soil in our study (hereinafter referred to as 'urban baseline'), we included all soil samples averaged in all yards, including those with average levels less than 400 ppm where we did not do any exposure-reduction measures. The urban baseline was determined by examining the relationship between the mean and geometric mean lead levels with distance from housing structure by fitting exponential curves to the data and evaluating the curves for their convergence (n=2920).

Results

Community-Based Activities. We relied upon and incorporated our community partners' knowledge of their neighborhoods and residents in the selection of sites for the lead-safe yard project and in the design of improved community outreach and education. As a result, the project moved from passive education methods, such as distributing educational pamphlets, to more active and interactive communication with a video, quiz, and discussion about lead hazards and the importance of lead-safe yards. A small number of businesses that were asked to donate materials and tools to the project did so, local businesses more so than large chain stores. The project offered employment opportunities for residents from the community to do the outreach, education, and landscaping work. Initially, we trained and employed youth; next we contracted with a local non-profit organization that builds community gardens and parks. In the last year of the project (Phase 3), we employed a pool of landscaping companies that work in the city of Boston with the intention of building their capacity to continue creating lead-safe yards as a component of their businesses and also to make the cost as competitive as possible. A focus group discussion with the landscapers, held midway through the last phase, yielded many interesting ideas and recommendations about materials and techniques used for future lead-safe yard projects.

Residents who agreed to participate in the Lead-Safe Yard project were educated about lead and its health effects by the outreach worker and kept informed of the soil sample results by the field team

and the landscaper and were given a maintenance manual at the culmination of the project. Finally, we disseminated the model of community-institution partnership as well as information about the technology used, sampling plan, and construction techniques in three ways: 1) making presentations to community organizations in many local forums and using local media, 2) creating a comprehensive handbook for community and public sector agencies interested in replicating the project, and 3) conducting a EPA-funded technology transfer workshop for city and state agencies from other EPA regions. All community, government, private sector and university project partners participated in the various aspects of project dissemination.

USEPA *Lead-Safe Yards...*

Profile of Study Yards and Intervention Costs. From the summer of 1998 through the fall of 2001, the EPA-funded Lead-Safe Yard Project completed 61 lead-safe yards. By 2001, the Lead-Safe Boston program completed 22 lead-safe yards, and the Office of Environmental Health completed six. Since some sampled yards were not eligible for the program because of low soil lead values and, in other cases, homeowners did not participate, more yards were sampled than were completed as lead-safe yards. All sample results from 102 yards, including replicate samples, are included in this analysis.*

*In total, 103 residential yards were sampled, and results from 102 yards are included in the data analysis. Data for one house were not available for analysis at the time of publication.

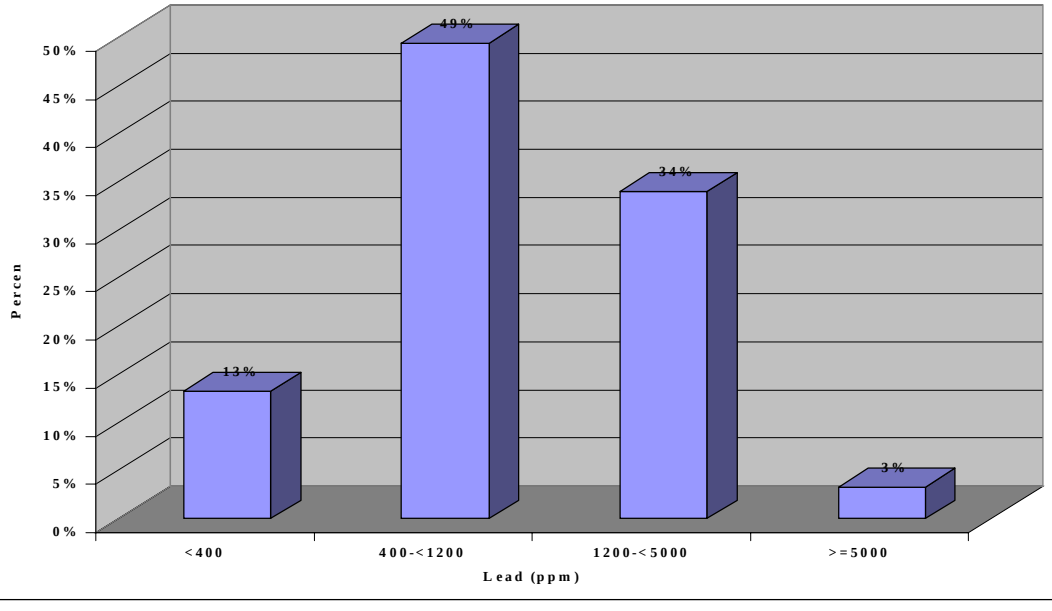
The Bowdoin Street neighborhood in Dorchester and the Dudley Street neighborhood in Roxbury consist mostly of older wood-framed homes with painted exteriors and unpaved yards where soil is present and soil lead is bioavailable. In this area, the median year housing structures were built is 1939. Additionally, 95 percent of homes were built prior to 1980, based on 1990 U.S. Census data (compared to the citywide average of 91 percent). Based on data from the 2000 census, children aged five years or younger constituted 7.9 percent of the population, compared to a citywide average of 5.5 percent. In general, these inner-city neighborhoods are densely populated with a higher percentage of children and an older housing stock than the city overall.

The average cost of interim measures per yard in Phases I and II was approximately $3000, with a breakdown of $2,100 average per yard for materials and construction costs and $900 per yard for project management and indirect costs. We were able to reduce costs in these phases by obtaining some materials at no cost, including gravel from a local company and wood chips and compost. The average cost of Phase III projects was $2800. These figures were not broken down by direct and indirect costs. Because many of the houses in Dorchester and Roxbury are two-and three-family dwellings, we were able to benefit multiple families for the cost of one lead-safe yard.

Construction time per yard ranged from one day to eight weeks, and the average time per yard was under one week. Factors that delayed or preempted yard treatment included inclement weather, availability of contractor and/or homeowner, and insufficient removal of large debris from yards (e.g. trash, appliances, and cars).

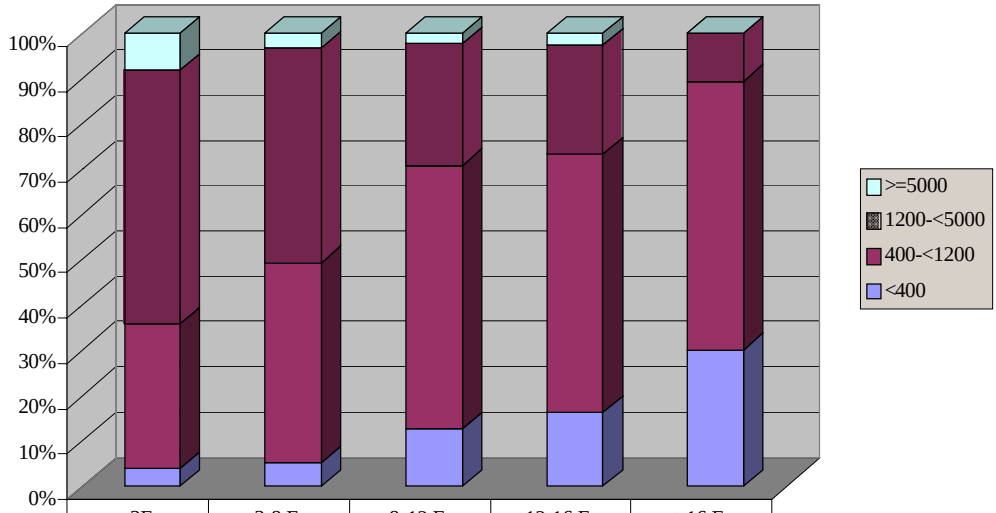
Profile of Soil Lead in Yards. For each yard, approximately 30 samples were collected yielding a total of 2920 sample results across 102 yards. The arithmetic mean for lead in soil at the yard level was 1456 ppm (range: 65 ppm – 12,875 ppm) and the standard deviation was 318 ppm. The geometric mean for lead in soil at the yard level was 1064 ppm (range: 580 ppm – 1631 ppm). Figure 2 describes the percent distribution of yards by lead concentration. Approximately 87 percent of yards had average lead concentrations exceeding 400 ppm and approximately half of the yards had average lead concentrations between 400 and 1200 ppm. Figure 3 provides percent distributions within each distance category to show how the concentration levels varied within each group. For example, 96 percent of all yard averages in the first distance category (0-3 feet) exceeded 400 ppm. More specifically, 32 percent were between 400 and 1200 ppm, 56 percent within the range of 1200 to 5000 ppm, and 8 percent exceeded 5000 ppm. For the last distance category (>16 feet), 70 percent of the yard averages in that distance group exceeded 400 ppm – 59 percent

FIGURE2
Percent Distribution of Yards by Lead Concentration



ranged between 400 and 1200 ppm, 11 percent ranged between 1200 and 5000 ppm, and none exceeded 5000 ppm.

FIGURE 3
Variation of Concentration Levels According to Distance



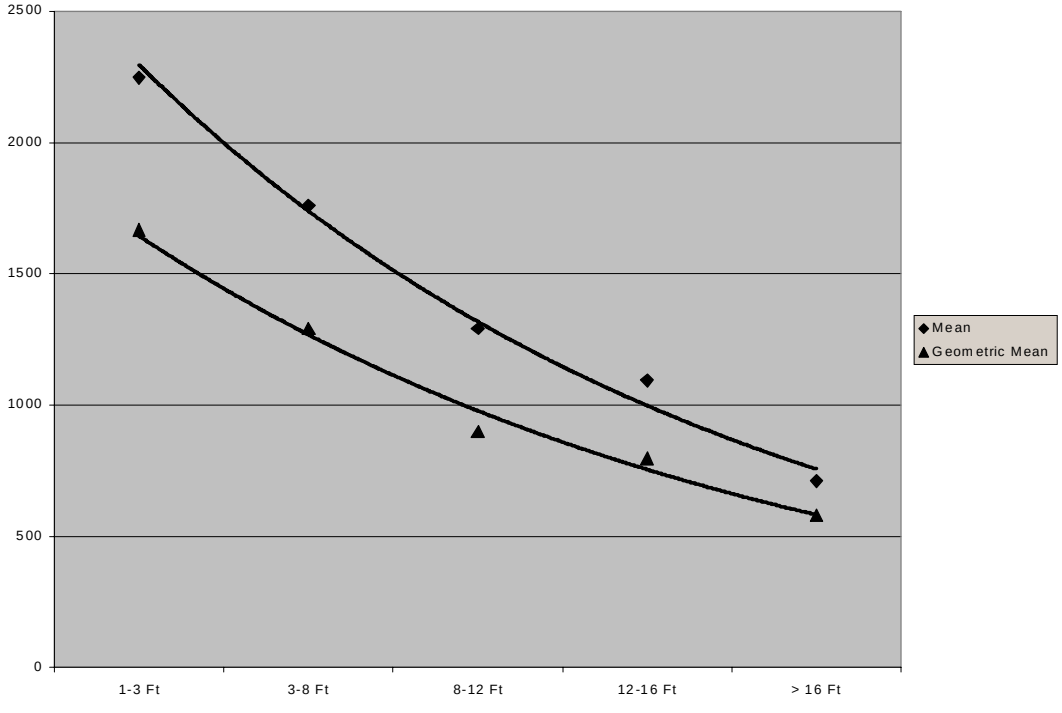
	<3Ft	3-8 Ft	8-12 Ft	12-16 Ft	>16 Ft
>=5000	8	3.16	2.15	2.53	0
1200-<5000	56	47.37	26.88	24.05	10.47
400-<1200	32	44.21	58.06	56.96	59.3
<400	4	5.26	12.9	16.46	30.23

Distance

To capture the impact of lead in yards from all historic and present sources, we evaluated arithmetic and geometric mean concentrations of lead by distance from building structure (n=102 yards). Figure 4 shows the arithmetic and geometric mean values for lead concentration averages in residential yards by five distance categories. The arithmetic mean values are shown to illustrate important excursions in lead levels that may exist in residential areas.

For example, within the drip line of the house (0-3 feet), the arithmetic mean was 2247 ppm. The minimum value was 173 ppm and the maximum value was 7495 ppm. The geometric mean value within the drip line was 1668 ppm. In contrast to the drip line of the house, at distances greater than 16 feet from the building structure, the arithmetic mean was 712 ppm. The minimum value was 65 ppm and the maximum value was 3238 ppm. The geometric mean value at distances greater than 16 feet was 580 ppm.

FIGURE 4
Arithmetic and Geometric Mean Values for Concentration Averages by Distance Categories



Discussion

The EMPACT pilot study set out to design affordable interim controls for soil lead that could be implemented in a timely and cost-efficient manner. The FPXRF *in-situ* analysis was an effective tool for the measurement of lead in urban soils. The technology allowed field staff to measure up to 30 samples per property in a relatively short time. It also aided in the choice of sampling locations, and remedy selections, facilitated feedback to program participants, and guided long-term yard management strategies. Moreover, field personnel were able to respond to extreme lead concentration readings by re-sampling that same day to determine whether the values were real or spurious.

EPA New England Regional Laboratory

This project also shed light on lead in soil as an urban hazard. The yard results support the widely held assumption that the highest concentrations of soil-lead are located in areas closest to the foundation of the house, referred to as the "drip line" of the housing structure. On average, geometric mean lead levels ranged from 1668 ppm within three feet of the building structure to 899 ppm at 8-12 feet from

the building structure and 580 ppm at 16 feet away. Overall, the data support the notion that soil lead concentrations decline the further one moves from the building foundation.

Notwithstanding this decline, soil lead levels across all distances from building structures exceeded EPA action levels of 400 ppm on average, for both the log-transformed and unadjusted data. Approximately 87 percent of the yards in the pilot neighborhoods had soil lead levels above 400 ppm and approximately 37 percent of these residential yards had soil lead levels above 1200 ppm, suggesting that, in an urban setting like Boston: 1) residential soil is an important pathway for adverse exposures to lead, and 2) all areas of the yard can pose risks to affected families given the blend of historic point sources (e.g., household exterior paint) and area sources (e.g., ambient deposition of lead from automobiles, local autobody shops, and smelting operations). The National Survey of Lead and Allergens in Housing found that an estimated 21 percent of homes have soil lead levels above 400 ppm and 12 percent have soil lead levels above 1200 ppm. These data reflect the maximum soil values for each housing unit.

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The geometric mean soil lead concentrations for the 102 yards studied in the EMPACT pilot project was 1064 ppm, which is consistent with other studies in the Boston area and beyond. Lanphear and others found that the geometric mean lead concentration for foundation soil was 1000 ppm in Rochester, NY. Rabinowitz and others reported a mean surface soil lead concentration for Boston of 600 ppm and "emergency lead poisoning area" average lead concentration of 2000 ppm.* Shinn and others reported a median soil lead level of 1773 ppm in a Chicago residential study area. While these data suggest the range of lead concentration in urban soils is high enough to warrant concern about its bioavailability as an urban health hazard, caution must be exercised when comparing these values for the purposes of generalizing about ambient lead levels in residential areas given the different metrics used for representing lead concentrations (e.g., arithmetic means, medians, geometric means).

Weitzman et al.

Lanphear

Rabinowitz

Shinn

*Emergency Lead Poisoning Areas (ELPAs) were designated by the city of Boston during the late 1980s. They were neighborhoods with the highest prevalence of lead poisoning among young children.

National studies of element concentrations in soils of the contiguous United States have shown that lead levels in virgin soil are estimated to range from 10 to 80 ppm but are subject to variation, from <10 to 700 ppm, when factoring in soil type and geographic location. In Boston, our study results suggest that estimates of an urban baseline, which reflects multiple sources of lead contamination, range from 580 to 712 ppm at distances greater than 16 feet from building structures. These values fall into the high end of the soil background ranges measured by Shacklette and others. Also noteworthy is that

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our urban baseline estimates are above the EPA "safe" level of 400 ppm for children's play areas. These data underscore the importance of lead in soil as a potential source of lead exposure and the need to integrate such information into local public health strategies to reduce population exposures to lead.

Conclusion

The Evaluation Process

The evaluation of the Lead-Safe Yard Project, managed by the National Center for Healthy Housing, had several objectives:

- to compare the precision of Field Portable XRF with other methods of measuring lead in soil, including Laboratory XRF, Inductively Coupled Plasma (ICP), and flame atomic absorption (AA)
- to determine whether residents' exposures to lead dust was reduced post-treatment
- to assess the durability of the treatments from two to 12 months after construction
- to assess participants' satisfaction with their role in the program, knowledge of methods of their reducing exposure to lead in soil, and their continued maintenance of the treatments.

The last three objectives represent important research questions in the context of community-based participatory research. If low-cost, small-scale methods to reduce exposure to lead in soil are to provide an effective alternative to more permanent abatement, the population most at risk must understand and demonstrate a willingness to adopt these measures. The size of yards in the project area, ranging from under 600 square feet to over 1800 square feet often rendered the cost of permanent removal and replacement prohibitive. Treatments that could be implemented with existing community resources have a greater chance of adoption, if the community is convinced of their merit.

The evaluation has collected extensive data on all phases of the soil project. For all properties, these data include:

- pre-intervention XRF readings
- field observations of the maintenance of the property exterior
- field observations of the treatments up to one year after treatment
- standardized face-to-face interviews with participants.

For properties enrolled in 2000, these data include:

- XRF readings for a sample of properties one year after the original readings were taken
- pre-intervention composite soil sample results
- pre- and post-treatment floor dust-wipe sample results
- dust lead loadings from vacuum samples of pre- and post-treatment door mats .

Future Directions

A promising plant-based remedial solution for lead in residential soil is a process called phytoextraction or phytoremediation, the uptake of metal contaminants from soil by plants. Recent research has shown that, with the addition of synthetic chelates such as EDTA, lead in soil can be solubilized and transported from the roots to the shoots of specific plants, such as sunflowers and Indian mustard. At elevated levels, lead in the plant tissue corresponds to the concentration of soil lead and the amounts of EDTA soil additive.

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With additional feasibility studies, it may be possible to develop a combination of approaches to using phytoextraction, including turf grass and other selective plants in open sunny land areas; portable growing bins in more shaded areas; and a central, municipally managed biotreatment site with greenhouses where contaminated residential soil could be deposited for phytoremediation and returned to yards when clean. This innovative, yet appropriate-in-scale, biology-based technology would enable urban communities to advance beyond interim controls for lead-safe yards, gardens, and play spaces to permanent solutions.

Bibliography

J. Ambler, *Attacking Poverty While Improving the Environment: Towards Win-Win Policy Options*, Poverty and Environment Initiative (New York: United Nations Development Programme and the European Commission, 2001).

D.K. Asante-Duah, "Investigating Potentially Contaminated Sites." In **(WHO IS THE EDITOR???)** *Managing Contaminated Sites* (Chichester: John Wiley & Sons,1996).

A. Aschengrau, A. Beiser, D. Bellinger, D. Copenhafer, M. Weitzman, "The Impact of Soil Lead Abatement on Urban Children's Blood Lead Levels: Phase II Results from the Boston Lead-In-Soil Demonstration Project," *Environmental Research* 67 (1994) 125-148.

M. Blaylock, D. Salt, S. Dushenkov, O. Zakharova, C. Gussman, Y. Kapulnik, B. Ensley, I. Raskin, "Accumulation of Lead in Indian Mustard by Soil-Applied Chelating Agents," *Environmental Science and Technology* 31(1997) 860-865.

J.K. Boyce, M. Pastor, *Building Natural Assets: New Strategies for Poverty Reduction and Environmental Protection* (Amherst, MA:Political Economy Research Institute, University of Massachusetts,2001).

E. Calabrese, EJ Stanek, "What Proportion of Household Dust Is Derived from Outdoor Soil?" *Journal of Soil Contamination* 1 (1992) 253-263.

Centers for Disease Control and Prevention, *Screening Young Children for Lead Poisoning: Guidance for State and Local Public Health Officials* (Atlanta, Center for Disease Control and Prevention, 1997).

R.J. Chaskin, "Building Community Capacity: A Definitional Framework and Case Studies from a Comprehensive Community Initiative," *Urban Affairs Review* 36 (2001) 291-333.

S. Clark, W. Menrath, M. Chen, S. Roda, P. Succop, "Use of a Field Portable X-Ray Fluorescence Analyzer to Determine the Concentration of Lead and Other Metals in Soil Samples," *Ann Agric Environ Med* 6 (1999) 27-32.

R.P. Clickner, D. Marker, S.M. Viet, J. Rogers, P. Broene, *National Survey of Lead and Allergens in Housing: Final Report - Volume 1: Analysis of Lead Hazards* C-OPC-21356 (Rockville, MD: WESTAT, Inc., 2001).

J.E. Fergusson, E.A. Forbes, R.J. Schroeder, D.E. Ryan, "Lead: Petrol Lead in the Environment and Its Contribution to Human Blood Lead Levels," *Science in the Total Environment* 50 (1986) 1-54.

M.T. Fullilove, R.M. Fullilove III, "Place Matters," in R. Hofrichter, ed., *Reclaiming the Environmental Debate: The Politics of Health in a Toxic Culture* (Cambridge, MA: Massachusetts Institute of Technology, 2000).

L. Goldman, B. Apelberg, S. Koduru, C. Ward, R. Sorian, *Healthy from the Start: Why America Needs a Better System to Track and Understand Birth Defects and the Environment* (Baltimore: The Pew Environmental Health Commission, 1999).

H.P. Hynes, R. Maxfield, P. Carroll, R. Hillger, "Dorchester Lead-Safe Yard Project: A Pilot Program to Demonstrate Low-Cost, On-Site Techniques to Reduce Exposure to Lead Contaminated Soil," *Journal of Urban Health* 78 (2001) 198-210.

"Identification of Dangerous Levels of Lead," *Federal Register*, Final Rule, 60:4 (January 5, 2001).

Institute of Medicine, *The Future of Public Health* (Washington, D.C.: National Academy Press, 1988).

Institute of Medicine, *Toward Environmental Justice: Research, Education, and Health Policy Needs* (Washington, D.C.: National Academy Press, 1999).

Institute of Medicine, *Rebuilding the Unity of Health and the Environment: A New Vision of Environmental Health for the 21st Century* (Washington, D.C.: National Academy of Sciences, 2001).

International Healthy Cities Foundation, *Overview and History of Healthy Cities* **(PLACE OF PUBLICATION?? PUBLISHER??**, 2001).

B. Israel, A.J. Schulz, E.A. Parker, A.B. Becker, "Review of Community-Based Research: Assessing Partnership Approaches to Improve Public Health," *Annual Review of Public Health* 19 (1998) 173-202.

J.P. Kretzmann, J.L. McKnight, *Building Communities from the Inside Out: A Path Toward Finding and Mobilizing a Community's Assets* (Evanston: ACTA Publications, 1993).

B.P. Lanphear, D.A. Burgoon, S.W. Rust, S. Eberly, W. Galke, "Environmental Exposures to Lead and Urban Children's Blood Lead Levels," *Environmental Research* 76 (1998) 120-130.

B.P. Lanphear, K. Dietrich, P. Auinger, C. Cox, "Cognitive Deficits Associated with Blood Lead Concentrations <10 ug/dl in US Children and Adolescents," *Public Health Reports* 115 (2000) 521-529.

K. Mahaffey, J.L. Annest, J. Roberts, R.S. Murphy, "National Estimates of Blood Lead Levels: United States, 1976-1980: Association with Selected Demographic and Socioeconomic Factors," *New England Journal of Medicine* 307 (1982) 573-579.

H.W. Mielke, J.C. Anderson, K.J. Berry, P.W. Mielke, R.L. Chaney, M. Leech, "Lead Concentrations in Inner-City Soils As a Factor in the Child Lead Problem," *American Journal of Public Health* 73 (1983) 1366-1369.

H.W. Mielke, P.L. Reagan, "Soil Is an Important Pathway of Human Lead Exposure," *Environmental Health Perspectives* 106, Supplement 1 (1998) 217-229.

National Research Council, *Understanding Risk: Informing Decisions in a Democratic Society* (Washington, D.C.: National Research Council, 1996).

J.L. Pirkle, D.J. Brody, E.W. Gunter, R.A. Kramer, D.C. Paschal, K.M. Flegal, T.D. Matte, "The Decline in Blood Lead Levels in the United States. The National Health and Nutrition Examination Surveys (NHANES)," *Journal of the American Medical Association* 272 (1994) 284-291.

Presidential/Congressional Commission on Risk Assessment and Risk Management, *Framework for Environmental Health Risk Assessment* (Volume I) 1997.

Presidential/Congressional Commission on Risk Assessment and Risk Management, *Risk Assessment and Risk Management in Regulatory Decision-Making* (Volume II) 1997.

M. Rabinowitz, A. Leviton, H. Needleman, D. Bellinger, C. Waternaux, "Environmental Correlates of Infant Blood Lead Levels in Boston," *Environmental Research* 38 (1985) 96-107.

H.T. Shacklette and J.G. Boerngen, "Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States," U.S. Geological Survey Professional Paper 1270, 1-63 (Washington, D.C.: U.S. Government Printing Office, 1984).

N.J. Shinn, J. Bing-Canar, M. Cailas, N. Peneff, H.J. Binns, "Spatial Continuity of Soil Lead Levels," *Environmental Research* 82 (2000) 46-52.

"Update: Blood Lead Levels—United States, 1991-1994," *Morbidity and Mortality Weekly Report* 46 (1997) 141-146.

U.S. Department of Health and Human Services, *Healthy People 2010: Understanding and Improving Health* (Bethesda: U.S. Department of Health and Human Services, 2000).

U.S. Environmental Protection Agency, *Integrated Report of the Urban Soil Lead Abatement Demonstration Project* EPA/600/P-93/001a (Washington, D.C.: U.S. Environmental Protection Agency, 1993).

U.S. Environmental Protection Agency, *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods* EPA Method SW-846 (Washington, D.C.: U.S. Environmental Protection Agency,1997).

U.S. Environmental Protection Agency, *Lead-Safe Yards: Developing and Implementing a Monitoring, Assessment, and Outreach Program for Your Community* EPA/625/R-00/012 (Washington, D.C.: U.S. Environmental Protection Agency, 2001).

U.S. Environmental Protection Agency, *What is EMPACT?* (Washington, D.C.: U.S. Environmental Protection Agency, 2001).

U.S. Environmental Protection Agency, New England Regional Laboratory, *Quality Assurance Project Plan for a Community-Based Environmental Lead Assessment and Remediation Program* (Lexington, MA: EPA New England Regional Laboratory, 1998).

J.A.M. van Oers, *A Geographic Information System for Local Public Health Policy* (Assen, Netherlands: Van Gorcum, 1993).

M. Weitzman, A. Aschengrau, D. Bellinger, R. Jones, J. Hamlin, A. Beiser, "Lead-Contaminated Soil Abatement and Urban Children's Blood Lead Levels," *The Journal of the American Medical Association* 269 (1993) 1647-1654.