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The HUD Lead-Based Paint

Abatement Demonstration (FHA)

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By
Dewberry & Davis
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THE HUD LEAD-BASED PAINT ABATEMENT DEMONSTRATION (FHA)

KEY PARTICIPANTS

DEWBERRY & DAVIS - Dewberry & Davis served as the project manager, responsible for coordinating and conducting supervision of each task, management of all abatement, and preparation of final reports. Dewberry & Davis personnel performed several operational functions, including field inspections of candidate units, development of abatement specifications, monitoring of abatement, solicitation of abatement contractors, contracting with abatement contractors, and data collection.

William G. Fry, P.E., Project Manager
Dennis (Chip) A. Harris, Assistant Project Manager
Mark S. Montgomery, Assistant Project Manager
R. Frederick Eberle, Field Coordinator
Richard A. Baker, Field Coordinator
Kenneth M. Shaffer, Field Coordinator
Douglas S. Williams, Field Coordinator
Rosemary H. O'Neill, Senior Technical Writer

SPEEDWELL, INC. - Speedwell developed the research design, including preliminary unit selection plan, all field data collection instruments (forms), and the final unit selection plan. Speedwell also compiled, analyzed, and reported the results of all data received during this project.

Anthony J. Blackburn, Senior Statistician
James T. Quinn, Analyst

KTA - TATOR, INC. - KTA was responsible for all XRF testing, development of LBP detection protocols, testing of units of housing, and conducting AAS and EP toxicity sampling where necessary.

Kenneth Trimber, Project Manager
Charles McCartney, Field Operations Manager
Dwight Weldon, Laboratory Director

TRACOR TECHNOLOGY RESOURCES, INC. - TRACOR developed worker protection and safety protocols, developed and conducted worker protection and safety training sessions for abatement contractors, and carried out environmental and personnel monitoring. They performed AAS laboratory analysis of samples and monitored data collection, and were responsible for final testing of all abated units.

Daniel Chute, CIH, Project Manager
Bonnie A. Barrows, Laboratory Director
Stephen R. Schanamann, CIH

KEY PARTICIPANTS (Cont'd.)

THE MARCOR GROUP - MARCOR provided lead-based paint abatement for unit prototype abatements in Baltimore, Maryland. Marcor also assisted in the development of the abatement methods, substrate identification, abatement monitoring, and data collection.

Jeffrey T. Paulding, Project Manager

U.S. DEPARTMENT OF HOUSING AND URBAN DEVELOPMENT

Office of Policy Development and Research

Ronald J. Morony, Director, Division of Innovative Technology
Ellis G. Goldman, Government Technical Representative
Nelson A. Carbonell, Government Technical Monitor
Dorothy R. Allen, Program Information Specialist

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

LIST OF APPENDICES

TABLE OF CONTENTS (continued)

LIST OF TABLES

EXECUTIVE SUMMARY

The toxic effects of lead on human beings, and particularly on young children, have been known for many years. Principal sources of lead in the human environment include the following: gasoline combustion, which contaminates the air, food, soil, and dust; lead solder, which contaminates drinking water and canned foods; lead-based paint, which contaminates soil and dust and can be ingested directly as paint chips; and industrial emissions and solid waste, which contaminate air, ground water, and workers' clothing.

The most severe cases of childhood lead poisoning typically result from ingestion of lead paint chips and are characterized by clinical symptoms such as mental retardation and convulsions. In recent years, however, much lower levels of blood lead, once believed to be safe and producing no clinically observable effects, have been shown to cause diminished motor control, permanent reductions in intelligence, and behavioral problems in young children. Subclinical levels of lead poisoning may result from ingestion of lead in house dust or in soil through the normal hand-to-mouth activity of young children. Further, lead-based paint has been shown to be a principal source of lead in house dust and in the soil surrounding dwelling units.

Lead in paint constitutes a potential hazard as long as the possibility exists that the paint may contribute to interior or exterior dust through abrasion of friction surfaces, peeling, flaking or chalking as the paint ages, or as a result of scraping and sanding in preparation for repainting. Effective lead-based paint abatement requires not only that leaded paint be removed or encapsulated, but also that all surface dust lead be eliminated. Dust lead may be present prior to abatement, or it may be generated by the abatement itself. In either case, clearance standards for abatement must include tests for the presence of dust lead.

Amendments to the Lead-Based Paint Poisoning Prevention Act (LPPPA) in 1987 and 1988 required the U.S. Department of Housing and Urban Development (HUD) to undertake a lead-based paint abatement demonstration program. The overall objective of the demonstration was to "utilize a sufficient number of abatement methods in a sufficient number of areas and circumstances to demonstrate their relative cost-effectiveness..." One component of the demonstration was conducted in HUD-owned, vacant, single-family properties and was completed in the fall of 1990. A public housing component is expected to be completed in 1991. This report describes the objectives, research design, experience and findings of the completed component, which is generally known as the FHA demonstration, named after the Federal Housing Administration, which held title to the houses.

Research Design

The demonstration was designed to achieve three major objectives with regard to lead-based paint abatement:

- To estimate the comparative costs of alternative methods of abatement
- To assess the efficacy of alternative methods of abatement
- To confirm the adequacy of worker protection safeguards during abatement

The final research design called for the abatement of lead hazards in 172 HUD-owned single-family properties located in seven cities (research sites) across the country, which were consolidated into five research groupings for statistical reporting purposes. Abatement was to be carried out under contract to HUD in full compliance with a set of guidelines[1] developed by the National Institute of Building Sciences.

To support comparisons of the costs and efficacy of alternative methods of abatement, the research design incorporated planned variation in the assignment of substrates requiring abatement to different methods of abatement. This was accomplished by defining six "Unit Abatement Strategies." A Unit Abatement Strategy consisted of a set of rules for determining which method of abatement would be employed on each substrate. The six strategies were: Encapsulation, Enclosure, Chemical Removal, Abrasive Removal, Hand-Scraping with a Heat Gun, and Replacement. As an example, encapsulation was the first choice method for the Encapsulation Strategy, but if encapsulation was not feasible, the strategy prescribed the second, third, and fourth choice methods. The same approach was followed for the other five strategies.

The methods of abatement that make up the Unit Abatement Strategies are encapsulation; abrasive removal; hand-scraping with a heat gun; chemical removal; enclosure with gypsum wall board, paneling, or exterior materials; and removal and replacement.

Encapsulation is a method of abatement that involves the coating and sealing of surfaces with durable coatings formulated to be elastic, long-lasting, and resistant to cracking, peeling, algae, and fungus.

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[1] The National Institute of Building Sciences, *Lead-Based Paint Testing, Abatement, Clean-Up and Disposal Guidelines*, Washington, D.C., March 1989.

Encapsulants are intended to prevent chalking, flaking, lead-containing substances from becoming part of house dust or accessible to children.

Abrasive Removal is a method of abatement that entails the removal of lead-based paint using mechanical removal equipment fitted with a high-efficiency particulate accumulator (HEPA) dust collection system.

Hand-Scraping with a Heat Gun is a method of abatement that entails the removal of lead-based paint using a heat gun to loosen the paint and a hand-scraping tool to remove the paint from the substrate.

Chemical Removal is a method of abatement that entails the removal of lead-based paint using chemical paint strippers.

Enclosure is the resurfacing or covering of surfaces, and sealing or caulking with mechanically affixed, durable materials so as to prevent or control chalking, flaking, lead-containing substances from being part of house dust or accessible to children.

Removal and Replacement is a method of abatement that entails removing substrates such as windows, doors, and trim that have lead-painted surfaces and installing new or de-leaded components free of lead paint.

After exhaustive testing of 304 candidate units for lead-based paint, 172 units were selected for use in the demonstration. These units were stratified by location and by the extent of lead hazards and were then randomly assigned to Unit Abatement Strategies. These dwelling units were located in Baltimore, MD; Washington, D.C.; Seattle, WA; Tacoma, WA; Indianapolis, IN; Denver, CO; and Birmingham, AL.

Throughout the abatement phase of the demonstration, data were collected on abatement worker activities, wage rates, materials use and materials costs to support estimates of the costs of abatement. Data were also collected on airborne lead concentrations, post-abatement surface dust lead, pre- and post-abatement soil lead concentrations, and workers' blood lead levels. Daily logs of problems encountered during abatement were also maintained and have been used to support findings on the efficacy of different methods of abatement.

A management and work plan was created; this included the research design, quality control and assurance processes, and procedures for the demonstration. From the outset of the development of the management and work plan and, most particularly, the research design, HUD sought the advice and consultation of a variety of Federal agencies with expertise in lead-based paint. In response to the direction from Congress, HUD and the Environmental Protection Agency executed a Memorandum of Understanding (MOU) on lead-based paint issues in April of 1989, which resulted in especially close coordination and assistance between those agencies in the development of the demonstration's objectives. A multi-agency task force on lead-based paint issues was established under the MOU and assisted in identifying the research and data needs for the demonstration. The abatement protocols employed in the demonstration -- the National Institute of Building Sciences (NIBS) Guidelines -- were developed by NIBS through a consensus process. These Guidelines governed all facets of testing, abatement, cleanup, disposal and worker protection for the demonstration.

The abatement of 172 dwelling units was then carried out. This process included the development of unique contract documents for the abatement of lead-based paint hazards; the solicitation and training of a sufficient number of abatement contractors to establish a "real world" bidding and costing process; and the execution of the abatement of the units, leaving them lead-hazard free according to the specifications and protocols of the demonstration. Concomitant with the abatement was the field monitoring, abatement contract observation, and data generation necessary to insure the completion of the abatement and the provision of the information required for research purposes. This included the bi-hourly collection of the activity of every worker for all abatement work, the taking and analysis of over 2,600 air samples, the collection and analysis of wipe samples for clearance of abated units, the collection and analysis of 455 paired pre- and post-abatement soil samples, and the generation of a variety of observations and findings related to the demonstration.

Testing for Lead-Based Paint

Selection of units for inclusion in the demonstration was based on the results of portable x-ray fluorescence (XRF) testing of interior and exterior substrates, carried out in 304 candidate units provided by HUD. XRF testing was performed in accordance with the NIBS Guidelines. A substrate is defined as a material that is coated, usually composed of wood, plaster, or metal, including items such as doors, window trim, walls, baseboards, etc. All substrates in the candidate units were tested with XRF systems, with the exception of substrates on which XRF systems physically could not be utilized due to size or surface irregularity, or on materials not conducive to XRF testing. A total of 26,758 substrates were tested in the 304 candidate dwelling units. The number of substrates identified to have lead values greater than or equal to 1.0 milligrams per square centimeter (mg/cm^2 - the threshold set forth in the NIBS Guidelines) was 4,863 or 18.2% of all substrates tested in the 304 candidate dwelling units.

After XRF testing was completed, 172 units initially selected from the 304 candidate dwelling units for inclusion in the demonstration were then retested using atomic absorption spectrometry (AAS) laboratory analysis of paint samples. AAS tests were performed on all substrates for which XRF testing was not feasible or whenever the XRF results lay in the range 0.2 to 1.8 mg/cm^2. In this respect, AAS testing in the demonstration went beyond the NIBS Guidelines, which require confirmatory AAS testing only when XRF results are in the range 0.5 to 1.5 mg/cm^2. In consultation with the National Institute of Science and Technology (NIST), it was determined that further testing with AAS was necessary to ensure a more accurate selection of substrates requiring abatement in the lower range of XRF results. A total of 5,828 AAS tests were performed in the proposed demonstration units, an average of 33.9 per unit. Of all substrates tested by AAS, 13.6% had test values of 1.0 mg/cm^2 or greater.

In addition to testing for lead-based paint on interior and exterior substrates, lead-in-soil testing was also conducted. Pre-abatement soil samples were taken at 152 dwelling units initially selected for abatement, and post-abatement samples were taken upon completion of all abatement activities in 160 dwelling units. Because some units initially selected for abatement were substituted with replacement units, a total of 455 paired (pre- and post-abatement) samples were collected, representing 130 dwelling units.

The mean value of the soil lead content across all samples was 755.0 parts per million (ppm) before abatement and 867.5 ppm after abatement. The difference of 112.5 ppm between the mean post-abatement and mean pre-abatement soil lead concentration is statistically significant at the 99% level. There is, therefore, essentially no doubt that the lead-based paint abatement work contributed significantly to the lead content of the soil in the immediate vicinity of the properties in spite of considerable efforts to contain the dust through the use of containment procedures outlined in the NIBS Guidelines.

Worker Protection and Personal Exposure Monitoring

Worker protection in the demonstration was carried out in accordance with the worker protection protocols in the NIBS Guidelines. These safeguards include training, medical monitoring, full respiratory protection, use of protective clothing, and personal breathing zone monitoring of airborne dust lead. During the course of the demonstration, the National Institute for Occupational Safety and

Health (NIOSH) conducted on-site observations of lead-based paint abatement activity and undertook its own program of environmental monitoring. NIOSH subsequently communicated its preliminary findings and recommendations to HUD. The recommendations included: discontinuation of the two-stage decontamination exit/entry facility; removal of polyethylene sheeting from windows, which should be open when a heat gun or chemical strippers are used; increased medical monitoring and promotion of more stringent personal hygiene practices; relaxation of the requirement for full protective clothing and respirators during exterior preparation, encapsulation/enclosure, interior preparation, and heat gun use on the exterior; and relaxation of the requirement for respirators for chemical stripping with caustic-based strippers. These recommendations were adopted for use in the remainder of the demonstration. A final NIOSH report on worker protection will be issued separately in the near future.

To determine the level of hazard exposure of the abatement workers, personal breathing area air samples were taken in each unit while abatement activities were taking place. The percentage of observations exceeding 30 micrograms of lead per cubic meter (ug/m^3) was 9.4% for the personal samples. Thirty micrograms of lead per cubic meter is the standard adopted in the NIBS Guidelines for a full-shift time-weighted average (TWA) exposure. It should be noted, however, that because the personal samples were taken while a worker was engaged in a single activity and were typically much shorter than an 8-hour TWA sample, these measures of exposure are not directly comparable.

Airborne lead concentrations were found to be strongly influenced by the Unit Abatement Strategy and by the method of abatement being used. Air samples in units assigned to the Hand-Scraping with Heat Gun Strategy were most likely to exhibit high levels of airborne lead (almost 16% of all air samples exceeding 30 ug/m^3) while the Encapsulation and Replacement Unit Abatement Strategies generated the least airborne lead (only about 4.0% of the all samples exceeding 30 ug/m^3). These findings were confirmed by examining the relationship between the abatement method in use and the level of airborne lead.

The effectiveness of negative air in reducing airborne lead levels during abatement was examined for the Hand-Scraping and Replacement Strategies only. When used in conjunction with the Replacement Strategy, which generated low levels of airborne lead, negative air did not appear to influence the level of airborne lead. However, when used in conjunction with hand-scraping with a heat gun, which generated the highest levels of airborne lead, negative air did appear to reduce airborne lead. The reductions were statistically significant for the area air samples and almost significant for the personal air samples. It should be noted that no measurements were made to determine the adequacy of the actual negative sir systems or equipment that were used in the demonstration.

Of the 237 abatement workers receiving initial blood lead tests, only two had blood lead levels of 30 micrograms per deciliter (ug/dl) or higher. Eighty-six (36.3%) of these workers had one or more follow-up tests during the course of the demonstration. Comparison of the initial and first follow-up blood lead levels of the workers who had follow-up tests is one measure of the effectiveness of the worker protection safeguards in force during the demonstration. Of 86 workers who had follow-up tests, 43 or exactly half were found to have reduced blood lead levels, 15 experienced no change in the blood lead level and 28, or approximately one third, had increases in blood lead levels. The highest follow-up blood lead level of any of the 86 workers was 22 ug/dl.

The Cost of Lead-Based Paint Abatement

A major objective of the demonstration was to develop reliable comparative estimates of the cost of abating lead hazards using different methods of abatement. The units selected for inclusion in the demonstration, while not representative of the universe of privately-owned housing, provided a test-bed to make these cost comparisons as well as to compare the effectiveness of different methods, as described later under "Efficacy." (Additionally, preliminary cost findings developed in the demonstration were used to estimate costs of abatement in HUD's Comprehensive and Workable Plan.[2])

The data used to support the cost estimates were obtained by having on-site industrial hygienists record the activities of abatement workers every two hours during the working day. Information on wage rates, materials utilization, and materials costs was obtained directly from the abatement contractors. Data on the quantities of substrates abated (i.e., square foot, linear foot, number of windows, etc.) were obtained from the quantity measurements that were incorporated in the bid documents. The cost estimates that were developed were made up of five elements: (1) direct labor costs of abatement; (2) indirect labor costs of abatement (i.e., work on set-up and cleanup not directly attributable to abatement of particular substrates); (3) direct materials costs of abatement (i.e., encapsulants, gypsum board, chemical strippers, replacement windows); (4) indirect materials costs of abatement (i.e., polyethylene sheeting, disposable protective clothing not directly attributable to the abatement of particular building substrates); and (5) contractor's overhead and profit. Estimated costs, by cost category and in the aggregate, are reported for each substrate type on a per square foot, per linear foot, or per substrate basis.

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[2] U.S. Department of Housing and Urban Development, *Comprehensive and Workable Plan for the Abatement of Lead-Based Paint in Privately Owned Housing: Report to Congress*, Washington, D.C.; December 7, 1990.

For the substrates reported, encapsulation is estimated to be the least expensive method of abatement in all but one instance -- interior doors, where replacement is estimated to be less expensive. When the costs of encapsulation and enclosure, the two abatement methods that contain rather than remove lead hazards, are compared, enclosure is estimated to cost 68% more for ceilings, 83% more for interior walls, 42% more for interior window trim, 103% more for soffits, 90% more for exterior walls, and 86% more for exterior window trim. The relative durability of encapsulants versus enclosure systems is not known at this time, and it is certainly plausible that enclosure systems such as wall board will be effective in containing hazards for much longer periods than will encapsulants and may therefore be competitive on a discounted future cost basis. It must also be noted that due to the durability issue, encapsulation of window systems for the purposes of lead hazard abatement is not permitted in the State of Maryland.

Of the three removal methods, it is apparent that chemical removal is generally not cost-competitive with hand-scraping with a heat gun or replacement. For baseboards, chemical removal is estimated to cost $8.96 per linear foot, compared to $4.51 for hand-scraping and $4.56 for replacement. This pattern is repeated for most other substrates. Chemical removal is 75% more expensive than replacement for door frames, 347% more expensive than replacement for doors, 44% more expensive than hand-scraping for windows, 185% more expensive than hand-scraping for window sills, and 88% more expensive than replacement for window trim. Chemical removal is, however, probably the only feasible removal method for exterior walls, although it is almost seven times more expensive than encapsulation and 3.5 times more expensive than enclosure for exterior walls.

When the two other removal methods -- hand-scraping with a heat gun and replacement -- are compared in terms of costs, they are frequently found to be quite similar. Replacement is clearly less expensive than hand-scraping for interior doors, interior door frames, interior window trim, exterior doors, and exterior window trim. Hand-scraping is less expensive for windows, both on the interior and exterior. For baseboards, interior window sills, exterior door frames, and exterior window sills, the differences in the estimated costs of the two abatement methods are not statistically significant. It should also be noted that, while replacement is 1.5 to two times more expensive than encapsulation for most substrates, it appears to be quite competitive for doors, both interior and exterior.[3]

[3]The cost estimates presented here are all on a "unit" basis, that is to say per square foot, per linear foot, or per system for windows and doors. To estimate the costs of abating lead hazards in a typical dwelling unit, it is necessary to combine these "unit" cost estimates with estimates of the number of square feet or linear feet of each substrate type and the number of windows and doors to be abated. It is also necessary to specify the methods of abatement to be employed.

An average abatement cost per housing unit was developed, based on the average square footage of surfaces with lead-based paint in housing reported in *The Comprehensive and Workable Plan for the Abatement Lead-Based Paint in Privately Owned Housing* and the abatement cost findings of this report. The average costs of abatement are $2,908 per unit for encapsulation and $7,703 per unit for removal. As the Comprehensive and Workable Plan shows (Table 4-7), many units will cost less and some with larger amounts of lead-based paint will cost more to abate. All of the above per unit costs reflect a combination of the least costly methods available within the respective encapsulation and removal strategies, including the use of replacement where appropriate (see Table V-3). As Table V-3 indicates, the least expensive method for all components is generally encapsulation. The exceptions are interior doors, for which replacement is the least expensive method, and windows, where replacement may be preferred because of the difficulty of successful encapsulation. Among the removal strategies, handscraping with a heat gun proved the least expensive method, except for windows and interior doors. For window sills and trim, however, the cost difference between chemical removal and handscraping is minimal.

The Efficacy of Lead-Based Paint Abatement

The "efficacy" of a method of abatement was assessed in terms of several key factors: the usability of a method; its hazard abatement effectiveness; and the amount of hazardous dust generated in the method's use as measured by air samples and post cleanup wipe samples. The demonstration was effective in evaluating these factors from either a subjective or objective approach, as highlighted below.

All dwelling units were subjected to visual inspection after abatement was completed. Failures to meet visual clearance standards were most frequently encountered when chemical or hand-scraping methods were used. Following visual clearance, all units were vacuum cleaned, wet cleaned with trisodium phosphate (TSP), and vacuumed again. At that point, wipe tests were carried out to determine whether the unit met surface dust lead standards. Taking wipe tests prior to sealing (priming or painting) was one divergence of the demonstration from NIBS Guidelines. It was felt that this process would develop a more useful set of data for determining this efficacy factor. Wipe tests were taken on floors, window sills, and window wells in every room impacted by abatement of each dwelling unit, except units in which no interior abatement was conducted (where no wipe samples were taken).

Initial wipe test failure rates ranged from 14.2% for window sills to 33.0% for window wells. The pass/fail rates were heavily influenced by the Unit Abatement Strategy (not to be confused with the abatement method) employed, with Chemical and Hand-Scraping Strategies having approximately 150%

higher failure rates than Replacement and Encapsulation Strategies. Altogether 113 units passed the surface lead clearance tests and the remainder did not pass after three cleaning iterations, although the failures were generally restricted to failure on a single surface. All units ultimately passed the NIBS Guidelines clearance requirements as a result of a sufficient number of cleaning iterations and/or sealing of abated surfaces that were wipe tested. Those that did not pass prior to sealing were most likely to be units that had been abated using either the Hand-Scraping or Chemical Strategies. This finding notwithstanding, it was also felt by those doing field inspections that the diligence and effectiveness of an abatement contractor's cleaning process, including daily cleanup procedures, had a major impact on the number of cleaning iterations required in a unit and the likelihood of the unit to pass the final wipe test clearance.

Encapsulation proved to be a simple and successful method of abatement almost everywhere except on friction surfaces such as window tracks and door jambs, where the encapsulation surface is subject to failure. Encapsulation generally improves the aesthetic value of the unit. The long-term effectiveness of encapsulants could not be addressed by the demonstration.

Enclosure was also quite easy to perform on large, flat surfaces and in many cases enhanced the appearance of the property. Enclosure may also provide the benefit of additional thermal insulation when applied to exterior surfaces. Enclosure requires basic carpentry skills and is occasionally difficult to install.

Chemical Removal methods were generally effective in abating lead hazards on a range of surface types and do not require a high level of worker skills. Chemical removal is, however, quite time-consuming, requires stringent worker protection, generates considerable hazardous waste, and does not work at low temperatures.

Hand-Scraping with a heat gun can be used on a wide variety of substrates by relatively unskilled workers. However, it can be a very labor-intensive method and it creates large amounts of airborne dust and fumes.

Replacement requires skilled workers but is versatile and generally improves the quality of a dwelling unit. Replacement does not generate significant hazardous waste.

Abrasive Removal proved to be ineffective/infeasible in almost every instance that it was attempted. Few surfaces were both large and flat enough to permit belts, pads, and disks to fit flush against them and, of those that did, most typically also had hard-to-reach areas where abrasive methods could not be used. Abrasive materials quickly became clogged with paint, requiring frequent and costly changes. Chemical removal methods were substituted for abrasive removal methods in most of these cases.

As a result of the elimination of abrasive removal as a viable method of abatement in dwelling units, the demonstration became a test of five, not six, different methods of abatement.

Waste Disposal

The issue of disposal of hazardous and non-hazardous waste was presented to appropriate State officials in the form of comprehensive waste stream analysis and a proposed waste disposal management plan in each of the demonstration sites. Review of these by State agencies resulted in considerable variations in direction. These variations directly impacted the disposal process, as the Contractor was required to tailor the disposal management plan on a state-by-state basis. Waste generated in Denver, Seattle/Tacoma, and Birmingham was treated as hazardous, while waste generated in Baltimore/Washington and Indianapolis was treated as non-hazardous.

The average cost of hazardous waste disposal in the three metropolitan areas where it was required was $1.18 per pound or $255.43 per dwelling unit. The use of chemical removal methods greatly increased the amount of hazardous waste generated. It was estimated that approximately one pound of hazardous waste was generated for each square foot from which paint was removed by chemical methods.

The demonstration clearly identified that post-abatement waste disposal considerations must be a vital part of an abatement plan. Local regulations, selection of abatement methods, and minimization of waste generation can have a significant impact on the cost and time frame of a program.

Abatement Contracting: Process and Performance

The demonstration design attempted, as far as was possible, to contract for abatement work in a manner that would allow generalization of the experience to future abatement efforts. These considerations led to the decision to package units in groups of approximately five units, to prepare bid documents for each group and to actively encourage competitive bids from local contractors.

The development of the bid, or contract, documents (Appendix A) included identification of the surfaces to be abated and development of generic specifications (i.e., specifications that did not identify proprietary products) for each abatement method . Lists of proprietary products, which had been identified through a public invitation were, however, provided to all potential abatement contractors without endorsement.

A total of 157 contractors were solicited to participate in the demonstration, of which 25 submitted bids and 16 were selected. The 16 included separate bids from different local divisions of the same national contractor. If these were consolidated, the number of participating contractors would be twelve.

The selected contractors were primarily from the asbestos abatement industry. This group was already familiar with worker protection requirements, but were weak on some of the construction skills required for lead-based paint abatement, such as carpentry. The other contractors, which were from the general contracting industry, had the requisite construction skills, but were unfamiliar with, and occasionally resistant to, the worker protection requirements of the demonstration.

The demonstration revealed a multitude of considerations with regard to abatement contractor selection and performance. Among these were the need for strong abatement contractor field supervision and the need for site enforcement of worker protection rules to ensure adherence to them.

Synthesis of Findings

Outlined below is a comprehensive review of the cost, practical utility, worker protection requirements, and overall effectiveness for each of the abatement methods utilized on the demonstration. For purposes of this discussion, it is useful to distinguish between methods of abatement that leave lead-based paint in place but make it inaccessible, and methods that remove lead-based paint from a dwelling unit. The former approach is represented by encapsulation and enclosure methods. The latter approach includes chemical removal, abrasive removal, hand-scraping with a heat gun and replacement of substrates. It should be noted that abrasive removal was initially attempted on each substrate specified by the research design. However, early field experience proved that lead-based paint removal by this method was feasible on a very limited selection of substrates; so limited in fact, that sufficient field data could not be obtained regarding its efficacy.

The findings of this report on the costs and efficacy of encapsulation and enclosure methods must be interpreted with caution, given the uncertainty about how long these methods will remain effective after installation. Additionally, cost considerations must include allowances for future costs of ensuring that these systems remain effective over time. With these reservations in place, the findings on the costs and effectiveness are now reviewed.

1. Encapsulation

Encapsulation is a method of abatement that involves the coating and sealing of surfaces with durable coatings formulated to be elastic, long-lasting, and resistant to cracking, peeling, algae, and fungus so as to prevent chalking, flaking, lead-containing substances from becoming part of house dust or accessible to children.

Encapsulation was found to be the least expensive of all the methods of lead-based paint abatement for all substrates except doors, where replacement is cost-competitive. Encapsulation typically costs 30% to 50% less than enclosure methods depending on the type of substrate to be abated. Compared to removal methods of abatement, the cost advantages of encapsulation are generally larger and are particularly evident for interior and exterior door frames, shelves, interior and exterior walls, soffits, interior and exterior windows, exterior window sills and window trim. It should be noted that in instances where both interior and exterior surfaces of a window require abatement, the additional cost for replacement of that window exceeds the cost of encapsulation. However, the durability issue of encapsulation on window systems remains a major factor in specifying encapsulation versus replacement of windows.

In terms of its worker protection requirements, encapsulation was found to be the abatement method that generated the lowest levels of airborne dust lead during abatement. Worker protection requirements were reduced at the suggestion of NIOSH when encapsulation abatement methods were in use and respirators were only used during surface preparation activities.

In terms of various measures of efficacy, encapsulation was found to be quite successful. Encapsulation worked on almost any substrate type given proper surface preparation and was particularly effective on hard-to-reach areas. Units abated using an Encapsulation Unit Abatement Strategy performed well in terms of clearance on wipe tests and generated less hazardous waste than units abated using other strategies. The demonstration did not address issues regarding the long-term durability of encapsulants.

2. Enclosure

Enclosure is the resurfacing or covering of surfaces, and sealing or caulking with durable materials mechanically affixed so as to prevent or control chalking, flaking lead-containing substances from being part of house dust or accessible to children.

Enclosure is a candidate method for abatement of lead hazards, particularly on large, flat surfaces such as ceilings and walls, although it was also used in the demonstration on window trim, columns and soffits. Because enclosure is uniformly more expensive than encapsulation, it would only be used if encapsulation was eliminated on the grounds of insufficient durability.

Enclosure would be preferred over removal methods for ceilings (where removal methods are generally not feasible), for exterior walls and soffits, and possibly for interior walls, where it costs about the same as hand-scraping with a heat gun.

Enclosure methods appear to generate very little airborne dust lead during abatement and their worker protection requirements are the same as for encapsulation.

Enclosure, although clearly not feasible for many substrate types, may confer aesthetic benefits in some dwelling units and will provide additional thermal insulation when used on exterior surfaces. Dwelling units assigned to the Enclosure Strategy did reasonably well in meeting wipe clearance standards, (although not quite as well as units assigned to the Encapsulation Strategy). Enclosure methods generate relatively little hazardous waste. As in the case of encapsulation, the demonstration did not address the long-term durability of enclosure.

All of the remaining methods tested in the demonstration physically remove the lead-based paint from a dwelling unit.

3. Chemical Removal

Chemical removal is a method of abatement that entails the removal of lead-based paint using chemical paint strippers.

The estimated cost of abatement using chemical strippers is consistently higher than the cost of removing lead-based paint by either hand-scraping or replacement methods. As noted in Chapter V, the differences between the cost of chemical removal and other removal methods are typically quite large, with differences ranging from 44% up to 347% greater, depending upon the type and detail of the substrate. Chemical removal is, however, typically the only feasible removal method for exterior walls, although it is estimated to be seven times more expensive than encapsulation and 3.5 times more expensive than enclosure.

Chemical removal creates more airborne dust lead than encapsulation, enclosure or replacement, but less airborne dust lead than hand-scraping. NIOSH recommended the use of more protective equipment (i.e., goggles, appropriate gloves, protective suits, and eye wash stations) when chemical stripping was used than when other methods of abatement were used.

Chemical removal can be used on a wide variety of substrates, but tends to be dependent on worker skill and is difficult in terms of daily cleanup and containment. Field experience demonstrated that chemical strippers are difficult or impossible to use outside of a moderate range of temperature. Dwelling units that had been assigned to a Chemical Removal Unit Abatement Strategy had the highest failure rates on wipe sample clearance tests and 38% of all units assigned to chemical removal never cleared on the wipe tests prior to priming or sealing. Lastly, units assigned to a chemical removal strategy generated far more hazardous waste than other units.

4. Hand-Scraping with Heat Gun

The hand-scraping with heat gun method of abatement entails the removal of lead-based paint using a heat gun and hand-scraping tool.

Hand-scraping appears to be less expensive than replacement for windows when only interior or exterior window surfaces require abatement, and about as expensive as replacement for baseboards, window sills, exterior door frames, and windows when both interior and exterior window surfaces require abatement. It is more expensive than replacement for interior doors and door frames, interior window trim, exterior doors and exterior window trim.

Hand-scraping with a heat gun generates more airborne dust lead than any of the other abatement methods with the possible exception of abrasive methods, which proved largely impractical and were not widely tested in the demonstration. Respiratory protection is therefore strongly recommended whenever hand-scraping is in use.

Hand-scraping is a versatile technique that can be used on a wide variety of substrates, but can be very labor-intensive, particularly when removing lead-based paint from large surface areas or detailed substrates. The heat gun worked better on wood than metal and masonry substrates. The effectiveness of the heat gun is largely dependent upon the experience of the user, and type of substrate. Units assigned to a Hand-Scraping Strategy had high failure rates on final wipe clearance tests and generated more hazardous waste than all other methods except chemical removal.

5. Replacement

Replacement is a strategy of abatement that entails removing substrates such as windows, doors, and trim that have lead-painted surfaces and installing new or de-leaded substrates free of lead paint.

Replacement of substrates appears to be the most promising of the removal methods in almost all circumstances. For doors, replacement is less expensive than any other method of removing lead-based paint, and it is comparable in cost to encapsulation. Replacement, while more expensive than encapsulation for substrates other than doors, is cheaper or about as costly as the least expensive of the other removal methods for all substrates. In the case of windows, replacement is cheaper than the other removal methods (hand-scraping with a heat gun or chemical removal) when both interior and exterior window surfaces require abatement and is about as costly as the other removal methods when only interior or exterior surfaces require abatement. However, in many older homes, the additional cost of window replacement may be recovered in energy savings.

Replacement appears to generate relatively little airborne dust lead and is comparable to encapsulation in this respect.

Replacement works well for almost all substrates and generally improves the quality of a dwelling unit except where the items replaced are very high-quality or possess inherent aesthetic value. Units assigned to the Replacement Unit Abatement Strategy performed well on post-abatement wipe clearance tests, where they did about as well as dwelling units assigned to the Encapsulation Unit Abatement Strategy. Replacement methods generated slightly more hazardous waste than encapsulation and enclosure methods, but much less hazardous waste than Hand-Scraping or Chemical Removal Unit Abatement Strategies.

The demonstration has allowed the development of a relatively well-defined set of findings available to the designers of lead-based paint abatement programs. These findings are founded on a fairly clear division of the costs of abatement methods and their efficacy factors. Once a determination is made by the designer as to the acceptability of the use of the methods of encapsulation and/or enclosure, (to wit, the two methods that allow the lead-based paint to remain in the dwelling, with their long-term effectiveness in question) the selection of methods has a reasonably defined path. Given the priorities of cost, hazardous materials, and other rehabilitation objectives, a decision on abatement methods can be made.

If encapsulation is determined to be an acceptable method in the sense that the long-term integrity of encapsulants seems assured, then the choice of abatement methods is very clear. All contaminated substrates would be encapsulated, with the possible exception of doors and windows, which might be replaced. In this way, lead-based paint hazards would be abated at the lowest possible cost, little airborne dust lead would be generated during abatement, abated units would usually pass final clearance wipe tests and there would be a minimum of hazardous waste.

If enclosure is determined to be an acceptable method, but encapsulation is not, the selection of abatement methods is somewhat more difficult. Because both enclosure and replacement generate little airborne dust lead and hazardous waste and because there is little difference between the two methods in terms of success on final wipe clearance tests, the choice should probably be made on the basis of cost. This would lead to a mixed strategy, where enclosure methods would be employed for ceilings, walls, exterior columns and soffits, and replacement methods would be used for baseboards, doors, door frames, windows, window sills and window trim.

In those cases where concerns about long term durability make enclosure or encapsulation unacceptable, replacement of the component would be the preferred choice. Possible exceptions to this are windows, which could be handscraped rather than replaced to reduce cost, and walls, where chemical removal may make sense because of the large surface areas to be abated.

I. INTRODUCTION

This report, entitled The HUD Lead-Based Paint Abatement Demonstration (FHA), is submitted to the United States Department of Housing and Urban Development by Dewberry & Davis in partial compliance with the requirements of Contract HC-5831 between those parties. The entire report is submitted in a three-volume document, with the first volume consisting of the detailed report, and the second and third volumes consisting of Appendices thereto. Throughout the report, the project is referred to as the demonstration. Dewberry & Davis and its subcontractors on the project team are referred to as the Contractor, and contractors that performed actual abatement services are called abatement contractors. A glossary of terms is provided immediately following Chapter IX.

A. The Lead-Based Paint Problem

The health risks to children created by the introduction of lead-bearing products into the human environment are now well-known. A comprehensive review of the problem was provided by the Agency for Toxic Substances and Disease Registry (ATSDR) in its 1988 report entitled, *The Nature and Extent of Lead Poisoning in Children in the United States: A Report to Congress.*[4] The findings of the ATSDR report, together with the results of other published public health investigations, were recently reviewed and summarized in the U.S. Department of Housing and Urban Development's (HUD's) *Comprehensive and Workable Plan for the Abatement of Lead-Based Paint in Privately-Owned Housing: Report to Congress.*[5]

A general understanding of the nature and extent of the health risks associated with lead-based paint in housing is necessary to put the findings of the demonstration in a proper context. While it is not a purpose of this report to replicate the detailed and carefully referenced review provided in the recently published *Comprehensive and Workable Plan*, it may be helpful to the reader to summarize the principal findings of the public health literature on childhood lead poisoning to provide a context for this report.

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[4]U.S. Department of Health and Human Services, Public Health Service, Agency for Toxic Substances & Disease Registry, *The Nature and Extent of Lead Poisoning in Children in the United States: A Report to Congress*, 1988.

[5]U.S. Department of Housing and Urban Development, *Comprehensive and Workable Plan for the Abatement of Lead-Based Paint in Privately Owned Housing: Report to Congress*. Chapter 2: Lead in the Environment: An Overview, 1990.

The toxic effects of lead on the central nervous system of human beings have been recognized for many years. High levels of lead in the body may produce clinically observable effects, such as mental retardation, convulsions or even death. Much lower levels of blood lead (PbB) in children, once believed to be safe and producing no clinically observable effects, have recently been shown to cause diminished motor control, permanent reductions in intelligence, and behavior problems.

In response to the growing medical evidence of the toxicity of lead at subclinical levels, the U.S. Public Health Service (PHS) has three times lowered the blood lead threshold for medical treatment. In 1971, PHS reduced the threshold from 60 micrograms of lead per deciliter (ug/dl) to 40 ug/dl. In 1975, the threshold was further reduced to 30 ug/dl, and it was again reduced in 1985 to 25 ug/dl. An advisory committee to the Centers for Disease Control is currently considering taking the position that blood lead levels in the range 10-15 ug/dl may permanently inhibit the neurological development of fetuses and young children.

ATSDR estimated that 200,000 black and white children below the age of six and living in metropolitan areas in 1984 had blood lead levels above 25 ug/dl. Using a threshold of 15 ug/dl, the ATSDR estimate increased twelvefold to 2,400,000. Inclusion of children in non-metropolitan areas belonging to all ethnic groups raised ATSDR's estimate of the number of children with blood lead levels over 15 ug/dl to between three and four million.

Lead-based paint is only one of a number of potential sources of lead in the environment that can contribute to the statistical pattern above. Other sources include emissions from combustion of leaded gasoline, industrial emissions of lead, lead in pipes and soldered joints in plumbing, and lead in food containers. The pathways by which lead from these sources finds its way into the human body include inhalation of air, ingestion of food and drinking water, and ingestion of non-food solids such as paint, house dust and soil dust.

The prohibition of leaded gasoline in new cars and the 1986 phase-down of lead in gasoline to 0.1 gram per gallon, together with reduced industrial emissions resulting from State regulation, resulted in a 94% reduction in the total atmospheric lead emissions from 1978 to 1987.[6] This

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[6]U.S. Environmental Protection Agency, Office of Air Quality Planning and Standards, "Review of the National Ambient Air Quality Standards for Lead: Exposure Analysis Methodology and Validation," (Staff Report) 1989, Page 11-5.

reduction in the amount of atmospheric lead emissions has been credited with a generalized cross-population decline in blood lead levels of 37% between 1976 and 1980, an average per capita blood lead decline of 5.4 ug/dl;[7] and the leaded gasoline phaseout was projected by ATSDR to increase the number of children falling below PbB levels of 15 ug/dl by a further 556,000 from 1985 to 1990.[8]

In reviewing the relative importance of other sources of childhood lead poisoning, the ATSDR report found drinking water to be "a potentially significant exposure source in both the home and in schools and other public facilities" and lead in food to be "declining in importance as a general exposure source." Of most relevance for this report, ATSDR concluded: "In terms of both quantitative impact and persistence of the hazard, as well as dispersal of the source into the population, leaded paint has been and remains a major source for childhood exposure and intoxication....Following close to leaded paint as a troublesome and persistent lead source is dust/soil lead, dispersed over huge areas of the nation."[9]

The most severe cases of childhood lead poisoning are typically associated with eating chips of lead-based paint or chewing on protruding surfaces coated with lead-based paint. Because lead may constitute as much as 40% of dried solids of pre-1940 paint,[10] ingestion of even small amounts of such paint may lead to greatly elevated blood lead and severe clinical symptoms of lead toxicity. Public health concern about preventing childhood lead poisoning that results from eating paint chips or gnawing on painted surfaces still finds expression in Federal, State, and local regulations that call for abatement of lead-based paint surfaces that are chewable and/or accessible to young children.

However, in more recent years, concerns about the prevalence and effects of subclinical levels of lead poisoning have led researchers to examine other pathways by which lead in paint may be ingested by young children. As a result of these efforts, there is now a broad consensus that

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[7]U.S. Environmental Protection Agency, Office of Health and Environmental Assessment, Air Quality Criteria for Lead, 1986.

[8]ATSDR, op. cit., p. VI-23.

[9]ATSDR. op. cit., p. VI-54.

[10]Farfel, Mark R., Annals of the Review of Public Health, *"Reducing Lead Exposure in Children"*, 1985, 6:333-60.

lead in paint is much more frequently ingested by young children through the medium of dust. Lead in paint is believed to contribute to dust as a result of scraping and sanding prior to repainting as well as peeling, flaking or simply chalking as paint ages. This dust lead may be located in either the interior or exterior of a dwelling unit depending on the location of the lead-based paint and the extent to which it is then imported or exported through windows and doors. It is now widely believed among researchers in this field that young children ingest and inhale both interior and exterior dust through normal play and normal hand-to-mouth activity.[11]

Recognition of the two major public health findings of recent years -- (1) the harmful effects of subclinical levels of childhood lead poisoning and (2) the importance of lead in dust as a pathway between paint lead and child blood lead -- has important implications for the way in which lead-based paint abatement should be conducted. Restricting lead-based paint abatement efforts to non-intact painted surfaces or intact chewable and painted surfaces that are accessible to young children will not necessarily be effective. Any lead in paint, regardless of its accessibility, constitutes a hazard as long as the possibility exists that the paint may contribute to interior or exterior dust through peeling, flaking or chalking as the paint ages. Furthermore, effective abatement requires not only that leaded paint be abated but also that all surface dust lead, both interior and exterior, be reduced to acceptable levels. Dust lead may be present prior to abatement or it may be generated by abatement activity itself. In either case, clearance standards for abatement should include tests for the presence of dust lead.

[11]One of the most convincing validations of this hypothesis is provided in a 1986 paper presenting interim findings of the Cincinnati Prospective Study of Low-Level Lead Exposure. In this paper, Bornschein et al. demonstrated the statistical significance of the following pathways: (1) Paint Lead --> Interior Dust lead, (2) Exterior Surface Lead --> Interior Dust Lead (3) Interior Dust Lead --> Child's Hand Lead (4) Child's Hand Lead --> Child's Blood Lead and (5) Interior Dust Lead --> Child's Blood Lead. At the same time, the direct pathways between Paint Lead and Exterior Surface Lead to Child's Hand Lead and to Child's Blood Lead were found to be statistically insignificant. See Bornschein, R. L.; Succop, P. A.; Krafft, K. M.; Clark, C. S.; Peace, B.; & Hammond, P. B. (1986) "*Exterior Surface Dust Lead, Interior House Dust Lead and Childhood Exposure in an Urban Environment*" in Trace Substance in Environmental Health, II, 1986, A Symposium, edited by D. D. Hemphill (University of Missouri, Columbia).

B. Legislative Background to the Demonstration

The central authorizing legislation for Federal lead-based paint regulation and abatement efforts is the Lead-Based Paint Poisoning Prevention Act of 1971 (LPPPA) and its subsequent amendments. As originally passed, the LPPPA required prohibition of the use of paint containing more than 1% lead by weight in all residential buildings receiving any form of Federal assistance and it authorized a national program to encourage and assist State and local governments to conduct mass screening programs for childhood lead poisoning.

In 1973, amendments to the LPPPA lowered the permissible lead content of paint to 0.5% by weight until December 31, 1974 and 0.06% after that unless the Consumer Product Safety Commission (CPSC) deemed the higher level to be safe, which it did in 1974. These amendments also required HUD to eliminate, to the extent practicable, lead-based paint hazards in pre-1950 housing receiving subsidies or applying for mortgage insurance, and also in pre-1950 Federally owned properties prior to sale. These amendments were implemented through HUD regulations issued in 1976. Further amendments to the LPPPA again placed the burden of determining safe levels of lead-in-paint on CPSC, which, in 1977, declined to find the 0.5% level to be safe, so that the maximum permissible lead content of paint became 0.06%. In 1978, under the authority of the Consumer Product Safety Act, CPSC banned the sale of lead-based paint to consumers and the use of lead-based paint in residences and other areas where consumers have direct access to painted surfaces.

In 1987, the LPPPA was comprehensively amended in several respects. A construction date cutoff of 1978 was set and, for the first time, the definition of lead paint hazard was extended to include accessible, intact and non-intact interior and exterior painted surfaces.

In addition to establishing certain additional testing and abatement requirements for public housing, 1987 and 1988 LPPPA amendments required HUD to undertake an Abatement Demonstration Program in both HUD-owned single-family and multi-family properties and in public housing. HUD was required, as part of the Abatement Demonstration Program, to "utilize a sufficient variety of abatement methods in a sufficient number of areas and circumstances to demonstrate their relative cost-effectiveness and their applicability to various types of housing." HUD was also required to prepare and transmit to the Congress, "a comprehensive and workable plan...for the prompt and cost effective inspection and abatement of privately-owned single-family and multi-family housing..." The 1988 amendments required a comprehensive and workable plan for the inspection and abatement of public housing.

The demonstration, mandated by the 1987 and 1988 amendments, essentially consists of two separate components, "private" and "public." The private component of the demonstration, which was conducted in HUD-owned (FHA), vacant, single-family properties, was completed in late 1990. The public housing component is now underway and is expected to be completed in 1992. This report describes the objectives, research design, experience and findings of the private, or FHA, component of the Lead-Based Paint Abatement Demonstration mandated by the LPPPA amendments of 1987.

C. Management and Work Plan

The management and work plan (Appendix B) created at the outset of the project delineated 13 tasks to be undertaken which can be divided into four phases enumerated below.

In Phase I, a management and work plan was created, which included the research design, quality control and assurance processes, and procedures for the demonstration. From the outset of the development of the management and work plan and, most particularly, the research design, HUD sought advice and consultation from a variety of Federal agencies with expertise in lead-based paint. Included in this list were the Environmental Protection Agency (EPA), the Centers for Disease Control (CDC), the National Institute of Occupational Safety and Health (NIOSH), the Occupational Safety and Health Administration (OSHA), the Consumer Product Safety Commission (CPSC), the National Institute of Environmental Health Sciences (NIEHS) and the National Institute of Standards and Technology (NIST). In response to the direction from Congress, HUD and EPA executed a Memorandum of Understanding (MOU) on lead-based paint issues in April of 1989, which resulted in especially close coordination between those agencies and the development of the demonstration's objectives. EPA was heavily involved in shaping the research design. In addition, an interagency task force on lead-based paint issues was established under the MOU and assisted in identifying the research and data needs for the demonstration.

The protocols employed in the demonstration were developed by the National Institute of Building Sciences (NIBS) through a consensus process and entitled *Lead-Based Paint Testing, Abatement, Cleanup and Disposal Guidelines*[12] (NIBS Guidelines). These NIBS Guidelines governed all facets of testing, abatement, cleanup, disposal, and worker protection.

Phase II consisted of the testing for lead-based paint in 304 single-family dwelling units out of a total of 370 made available to the demonstration by HUD. These dwelling units were located in five research groupings: Baltimore, MD/Washington, D.C.; Seattle/Tacoma, WA; Indianapolis, IN; Denver, CO; and Birmingham, AL. These seven research sites became the center of abatement activities for the remainder of the demonstration.

The testing program consisted of a multi-visit program to all of the units. All 304 units were tested extensively by the use of portable x-ray fluorescence analyzers (XRF). The data for every potential substrate in each one of the units, and its resulting XRF testing results (where possible) were recorded and developed into a data base organized by unit and location. Through the application of the research design program, from these 304 units, approximately 172 units were identified as meeting the needs of the demonstration in terms of being applicable units to undergo abatement to create the research data.

The next step of the testing phase was to return to the prospective units for testing, utilizing atomic absorption spectrometry (AAS) sampling and analysis. This testing program required almost 6,000 AAS samples in the subject units, covering all substrates that had an XRF test result between 0.2 and 1.8 milligrams per square centimeter (mg/cm^2) of lead, and all substrates that were not conducive to XRF testing. The results of the testing phase of the demonstration, therefore, yielded optimum units to undergo abatement for the provision of the necessary data to meet the objectives of the demonstration. The testing results also generated a significant amount of data, which have been provided to agencies outside of HUD to be utilized in the analysis of the testing methods, which was beyond the scope of the demonstration.

Phase III of the demonstration was the completion of the abatement of 172 dwelling units at the seven research sites. This process included the development of unique contract documents

[12]NIBS, op. cit.

for the abatement of lead-based paint hazards; the solicitation and training of a sufficient number of abatement contractors to establish a "real world" bidding and costing process; and the execution of the abatement of the units, leaving them lead-hazard free according to the specifications and protocols of the demonstration. Concomitant with the abatement was the field monitoring, abatement contractor observation, and data generation necessary to insure the completion of the abatement and provision of the information required for research purposes. Among the functions of this phase was the bi-hourly recording of each worker's activity for all abatement work, the taking and analysis of over 2,600 air samples, the collection and analysis of wipe samples for clearance of abated units, and the generation of observations and findings in addition to those dictated by the objectives of the demonstration.

Phase IV of the demonstration was the assembly of all of the data generated during the abatement effort and its analysis and presentation in this final report.

D. Organization of this Report

This report on the findings of the FHA component of the Abatement Demonstration Program is organized into nine chapters, including this introduction. In Chapter II, the research design for the demonstration is presented and discussed. Chapter III describes the methods used to test for the presence of lead-based paint hazards in the demonstration and reports on the scope of the testing program and the extent of lead-based paint hazards in the dwelling units selected for abatement.

Chapter IV discusses the protection of lead-based paint abatement workers, which was a major concern throughout the demonstration. The measures taken to provide protection, as well as the effectiveness of those measures, assessed through personal exposure monitoring, are reviewed and discussed.

Chapter V addresses one of the major research objectives of the demonstration, which was the development of reliable estimates of the costs of abatement using different methods of abatement on different substrate types. This chapter also presents the methods used to collect and analyze data on the costs of abatement, as well as estimates of the per-square-foot, per- linear-foot and per-unit (windows and doors) costs of abatement, organized by abatement method and by substrate type.

In Chapter VI, findings on the efficacy of lead-based paint abatement in the demonstration are presented and discussed. Efficacy is broadly construed to include the practical usability of an abatement method, visual clearance testing, wipe-test clearance testing, and final cleaning requirements. The relationship between efficacy and abatement methods is examined. In Chapter VII, hazardous waste disposal issues encountered in the demonstration are reviewed and the influence of abatement methods on hazardous waste disposal requirements is analyzed.

Chapter VIII discusses the process of lead-based paint abatement contracting, which was carried out through a negotiated bidding process designed to insure that several different contractors would be active in each metropolitan area.

Lastly, in Chapter IX, the practical lessons learned from the experience of carrying out lead-based paint abatement in 172 dwelling units using different methods of abatement are presented and discussed, and synthesized with the research findings. It is hoped that these lessons will be of value to individuals and agencies who have to make decisions regarding lead-based paint abatement and wish to benefit from the experience of the demonstration.

II. RESEARCH DESIGN

A. Objectives of the Demonstration/Research Design Objectives

The demonstration resulted in the abatement of lead-based paint hazards in 172 units of HUD-owned, vacant, single-family dwelling units. When these units are returned to the privately owned, occupied housing stock through HUD's property disposition programs, they will be, in accordance with the standards set up for the demonstration, free of lead-paint hazards. This benefit is, however, incidental to the main purpose of the demonstration, which was to develop and analyze experimental data on the experience of carrying out lead-based paint abatement under the NIBS Guidelines.

The specific research objectives of the demonstration can usefully be grouped into three major categories:

- Estimating the Comparative Costs of Alternative Lead-Based Paint Abatement Methods
- Assessing the Efficacy of Alternative Lead-Based Paint Abatement Methods
- Confirming the Adequacy of Worker Protection Safeguards Used in the demonstration

The research design of the demonstration was intended to support findings on each of these topics.

1. Estimating the Costs of Alternative Lead-Based Paint Abatement Methods

At the outset of the demonstration, it was assumed that the costs of abating lead-based paint hazards in an individual dwelling unit vary according to the number and type of substrates to be abated, the methods of abatement employed on each substrate, the nature and extent of worker protection safeguards employed during abatement, and the stringency of the clearance standards used to determine when abatement has been satisfactorily completed. The costs of abatement also vary with the unit costs of labor and materials input and the nature of the contracting process. The design of the demonstration was intended to examine how costs are affected by some, but not all, of these factors.

To support estimates of how costs vary with the number and type of substrates requiring abatement, units were selected with different lead-based paint abatement needs, and costs were estimated on a unit basis (i.e., per square foot or per linear foot). Estimating the differences in the costs of abatement attributable to the use of different methods of abatement required a research design that incorporated planned variation in the assignment of abatement methods to different substrates, so that conclusions could be drawn about the cost of using different methods of abatement on similar substrates.

Planned variation in the abatement requirements of the dwelling units and in the methods of abatement employed is central to the research design of the demonstration and serves the objective of supporting estimates of the relationship between abatement costs on the one hand and abatement needs/abatement methods on the other hand.

Planned variation in worker protection requirements and in post-abatement clearance standards was, however, not a feature of the demonstration, although both worker protection requirements and clearance standards influence the costs of abatement. As a result, data from the demonstration cannot be used directly to support findings on how costs could be decreased by relaxing NIBS Guidelines safety requirements and/or clearance standards. This was a design decision made at the outset of the project that reflected the view that experimentation with either worker safety or potential post-abatement lead hazards was unacceptable.

2. Assessing the Efficacy of Alternative Lead-Based Paint Abatement Methods

The research objectives of the demonstration included a detailed examination of the abatement experience in the demonstration, with particular emphasis on comparisons of different abatement methods in terms of how well they worked in different circumstances; how much dust lead was generated in the course of abatement; how post-abatement dust lead loadings varied with the methods of abatement employed; how much final cleaning effort was required to meet clearance standards for surface dust lead; and how many units met clearance standards for surface dust lead. This information should be of value and interest to all persons considering undertaking residential lead-based paint abatement in the future.

3. Confirming the Adequacy of Worker Protection Safeguards used in Lead-Based Paint Abatement

As the first major test of the adequacy of the NIBS Guidelines for worker protection during lead-based paint abatement activities, the demonstration provided an opportunity to verify that the NIBS worker protection protocols were effective in insuring worker safety. This was the third major research objective.

B. Limitations of the Demonstration

The principal limitations of the demonstration are of two kinds. In the first place, as noted above, the demonstration was designed to develop findings on the costs, efficacy, and safety of lead-based paint abatement carried out under the NIBS Guidelines. While the NIBS Guidelines provide considerable flexibility with respect to the methods of abatement employed, no variation is permitted for clearance standards and worker protection protocols. The demonstration does not, therefore, address the issue of what abatement would cost, or how safe and effective it would be, if abatement were to be conducted under different standards.

In the second place, the demonstration may also be limited in the extent to which its findings can be safely generalized to the universe of all housing requiring abatement. A number of qualifications to the universal applicability of the findings presented in this report should be acknowledged. It should be noted that the demonstration does not address longitudinal aspects of lead-based paint abatement.

All the dwelling units abated in the demonstration were vacant, single-family homes owned by HUD as a result of FHA foreclosure action. An effort was made to identify vacant, multi-family buildings owned by HUD for inclusion in the demonstration, but this effort was unsuccessful. To the extent that the costs of lead-based paint abatement in multi-family buildings differ from the costs in single-family buildings, the demonstration results may not be representative of the universe of all privately owned housing.

All the units in the demonstration were vacant and unfurnished. The costs of abatement presented herein do not include any costs of temporary relocation of families during abatement or any costs associated with protecting or moving furniture. Since many units requiring abatement are both furnished and occupied, the demonstration cost estimates may be artificially low and unrepresentative of the costs that would be incurred in a non-experimental setting.

All abatement activity in the demonstration was performed on a "stand-alone basis" in the sense that it was not undertaken in conjunction with other renovation activity. To the extent that fewer costs may be attributable to abatement when it is carried out concurrent with other renovation, the demonstration cost estimates may be biased upward. Abated surfaces were primed and prepared for final painting. Abated houses were left in equal or better condition than their original state. To the extent that refinishing abated surfaces would typically be required in occupied properties, the demonstration cost estimates may be biased downward. No information is available to determine the direction and amount of bias when these effects are netted out.

Lastly, it should be noted that, although vigorous efforts were made to recruit bidders on each of the demonstration sites and all abatement was put out to bid, it is still not possible to assess whether or not the prices charged by abatement contractors in the demonstration were representative of the prices that would prevail if lead-based paint abatement were to be undertaken on a much larger scale across the country with an established and skilled lead-based paint abatement contracting industry. It would seem that this is an unavoidable limitation of any demonstration of largely untried methods and protocols for use by an industry that has, to all intents and purposes, not yet come into existence.

C. Design of the Demonstration

The design of the demonstration focused on contrasting different methods of abatement in terms of cost and efficacy. The design issues for the demonstration sought to develop detailed answers to three broad questions:

(1) Which properties should be abated in the course of the demonstration?

(2) What methods of abatement should be tested in the demonstration?

(3) How should different substrates requiring abatement be assigned to different methods of abatement?

The resolution of each of these three questions, and the reasons for the choices made, are reviewed in turn in this section. The complete text of the research design is included as Appendix C.

1. Selection of Dwelling Units to be Abated

The demonstration was limited to HUD-owned (i.e., FHA-foreclosed) properties. It was determined that, ideally, the properties included in the demonstration should -- (1) include both single-family and multi-family structures, (2) exhibit reasonably representative regional variation, and (3) contain sufficient lead-based paint hazards to permit adequate abatement data to be accumulated.

Staff of HUD's Office of Policy Development and Research initiated planning for the demonstration by acquiring information on the number and type of properties then in the property disposition inventory in each HUD field office. An exhaustive effort to find suitable multi-family structures possessing lead-based paint and other appropriate characteristics such as interior common corridors proved unsuccessful. As a result, the demonstration was limited to single-family homes.

Based on a review of the number and age of single-family properties in inventory at each of the HUD field offices, a decision was made to conduct the demonstration in Baltimore, MD; Washington, DC; Indianapolis, IN; Birmingham, AL; Seattle, WA; Tacoma, WA; and Denver, CO. These seven research sites were consolidated into five research groupings for statistical reporting purposes. Using age as a benchmark for potential lead-based paint, it was anticipated that the single-family inventory in these cities would include 350-500 properties with potentially hazardous levels of lead-based paint.

A total of 370 properties were identified by the Office of Policy Development and Research staff and the HUD field offices as candidates for the demonstration. These were then inspected and 66 properties were eliminated from further consideration, generally because of their poor condition. The remaining 304 properties were then screened for the presence of lead-based paint using portable XRF testing. All substrates on which an XRF analyzer could be used were tested and properties were ranked according to the preliminary estimate of the number of substrates requiring abatement using an abatement standard of 1.0 mg/cm^2, except in Maryland, where the standard is 0.7 mg/cm^2 (0.5 mg/cm^2 for AAS testing). The protocols used in XRF testing are presented in Appendix D.

All 304 properties were then stratified into a "4 x 5" design using four levels of lead hazard measured by the number of substrates to be abated (0-9, 10-29, 30-59, 60 or more) and the five research groupings. This stratification was performed to insure that each area would be adequately represented in the final sample and that the units selected would exhibit a range of lead hazards to be abated. The initial property selection procedure then called for eliminating all properties with fewer than 10 substrates requiring abatement on the grounds that it would not be cost-effective to include these units, and then selecting 172 properties by stratified random sampling within the remaining 15 cell (3 x 5) design.

The sample drawn initially using these procedures was modified somewhat, with the inclusion of six units in the 1-9 range, as the demonstration progressed. Additionally, substitutions were made for 11 of the sampled properties in order to reduce the costs of abatement without compromise to the design of the demonstration. The final property selection design is presented in Table II-1.

Table II-1

FINAL PROPERTY SELECTION DESIGN: NUMBER OF DWELLING UNITS BY SITE AND BY NUMBER OF SUBSTRATES REQUIRING ABATEMENT

	Number of Substrates Requiring Abatement				
Site	1-9	10-29	30-59	60+	All
Baltimore/ Washington, DC	0	10	13	9	32
Indianapolis	5	17	11	1	34
Birmingham	0	8	7	8	23
Seattle/Tacoma	1	6	8	11	26
Denver	0	21	23	13	57
Total	6	62	62	42	172

2. Selection of Abatement Methods

The research design was prepared to be as inclusive as possible in selecting methods of abatement to be utilized so that all existing methods could be tested.

The NIBS Guidelines identified three different Lead-Based Paint Abatement Strategies:

(i) Replacement - "the removal of components such as windows, doors and trim that have lead-painted surfaces and installing new components free of lead-containing paint."

(ii) Encapsulation - "making lead paint inaccessible by covering or sealing painted surfaces."

(iii) Paint Removal - "stripping the lead paint from painted surfaces of components. There are two types of paint removal: on-site and off-site."

For the purposes of the demonstration, more specificity was required. For encapsulation, it was necessary to distinguish between sealing and enclosure because the construction methods involved were different, the unit costs might be different, and the durability of sealants might be more questionable than the durability of enclosure materials. Accordingly, the NIBS "encapsulation" category was subdivided into two categories in the demonstration:

(i) Encapsulation: Sealing lead-based paint with a material that bonds to the surface, such as acrylic or epoxy coatings or flexible wall coverings.

(ii) Enclosure: Covering lead-based paint using systems such as gypsum wall board, plywood paneling, and aluminum, vinyl or wood exterior siding.

A further adaptation of the NIBS classification was to subdivide the on-site paint removal category into "chemical," "abrasive," and "hand-scraping with a heat gun" methods. This was necessary because, if abatement contractors were free to choose any of these three on-site paint removal methods, some methods might seldom or never be chosen and little or no data on their costs and effectiveness would be obtainable.

Lastly, the NIBS "replacement" category was enlarged to include chemical stripping off-site. This reflected a view that replacement with substrates that were new or chemically stripped off-site would be identical in terms of on-site dust generation and that the choice between the two should, absent aesthetic considerations, be based on cost and left to the abatement contractor.

This resulted in six methods of abatement to be tested in the demonstration:

(1)	Encapsulation	(4)	Abrasive Removal
(2)	Enclosure	(5)	Hand-scraping with Heat Gun
(3)	Chemical Removal	(6)	Replacement

The "abrasive removal" method was further subdivided into -- (1) sanding, (2) blasting, and (3) grinding -- for use in the final design.

It would, of course, be possible to further disaggregate/subdivide methods of abatement by distinguishing methods in terms of particular proprietary products, such as chemical paint strippers, sanding equipment, encapsulants, etc. This would have greatly compromised the statistical power of the research design and would have led to comparisons between the efficacy of competing products, a task that was outside the scope of the demonstration.

3. Assignment of Abatement Methods to Substrates

Once the properties and methods of abatement to be tested had been selected, it remained to decide which method of abatement was to be employed on each of the substrates requiring abatement in all of the properties selected.

The approach that was adopted for the demonstration reflected a desire to achieve the sharpest possible contrasts between properties with respect to dust lead generation during abatement. The alternative of using all six methods of abatement on different substrates within a single property would have been unrepresentative of construction practice and uneconomical. It would also have led to a situation in which variations in airborne dust lead or surface dust lead between properties would be unattributable to the methods of abatement employed. However, it was also unreasonable to expect that it would be feasible to use only one abatement method throughout a given dwelling unit.

Accordingly, the decision was made to assign abatement methods to substrates through the device of so-called "Unit Abatement Strategies."

A Unit Abatement Strategy consists of a set of rules that specify, for each substrate type within a unit, which method of abatement is to be employed. Thus, assignment of a dwelling unit to a Unit Abatement Strategy has the effect of completely specifying how lead-based paint will be abated in that unit.

The demonstration employed six Unit Abatement Strategies corresponding broadly to the following generic methods of lead-based paint hazard abatement:

(1) Enclosure
(2) Encapsulation
(3) On-site paint removal by Abrasive methods
(4) On-site paint removal by Chemical methods
(5) On-site paint removal by Hand (heat gun)
(6) Substrate replacement

The generic method used to characterize the Unit Abatement Strategy was always the first choice for each substrate type to be abated. However, if the first choice method was not feasible (e.g., sanding ornate surfaces), the Unit Abatement Strategy specified second, third and fourth alternatives.

These rules were designed so that what were believed to be low dust generating methods were substituted for low dust generating methods, and medium dust generating methods were substituted for medium dust generating methods. In this way, the sharpness of the contrasts between the efficacy of different methods, as measured by dust lead residues, was maintained.

The rules that define the Unit Abatement Strategies are shown in Table II-2. These rules, when combined with a list of feasible methods for each substrate type, fully define the six Unit Abatement Strategies utilized in the demonstration.

Table II-2

UNIT ABATEMENT STRATEGIES

Preference Ordering for Abatement	Enclosure	Encapsulation	Abrasive Removal	Chemical Removal	Hand-Scraping with Heat Gun	Replacement
1st Choice	Enclose	Encapsulate	Abrasive	Chemical	Hand	Replace
2nd Choice	Encapsulate	Enclose	Chemical	Abrasive	Replace	Hand
3rd Choice	Chemical	Chemical	Enclose	Enclose	Chemical	Chemical
4th Choice	Replace	Replace	Replace	Replace	Enclose	Enclose

As noted earlier, the Replacement Unit Abatement Strategy left it to the abatement contractor to decide whether or not substrates should be replaced with new substrates or with substrates from which the lead-paint has been chemically stripped off-site. Also, three different methods of abrasive removal were specified: sanding, grinding, and vacuum blasting. Finally, the design required that when (what were to be believed to be) high dust generating Unit Abatement Strategies (Hand-Scraping with Heat Gun and Replacement) were used, negative air pressure devices should be installed during abatement in approximately half of the units assigned to these strategies.

The statistical design of the demonstration was completed by the assignment of units to the Unit Abatement Strategies. This was done using stratified random sampling to insure that there was no confounding between the Unit Abatement Strategy, the number of substrates requiring abatement, and the location of the property. The final design is presented in Table II-3.

D. Data Collection

The plan for data collection during the demonstration reflected the three major objectives of the research design: (1) cost estimation, (2) assessment of the efficacy of abatement, and (3) confirmation of the adequacy of worker protection safeguards.[13]

1. Cost Data Collection

The collection of data to support the cost estimates was carried out in three different ways. First, take-offs of the quantities of each substrate requiring abatement were made and used in the preparation of bid documents and in the estimate of unit costs. Second, on-site observations were made of abatement worker activity. Third, information on labor rates and materials costs was obtained through an abatement contractor survey. The second and third of these data collection efforts are described here.

It was initially planned to have the on-site industrial hygienists (IH) record the start and finish times of tasks performed by each worker in each unit being abated. It became quickly apparent that this was not feasible because the IHs were required to visit several properties several times on each working day and they could not, therefore, be present to record the start and finish times of all tasks/activities.

This problem was solved by having the IHs record the location and activity of each worker approximately four times in each working day. These data support estimates of the number of hours that each worker spent on a particular task, albeit there is an element of measurement error. The information recorded by the IHs included the date

[13]Data collection activities also included lead-based paint testing data, which are not discussed here, but which are described in the next chapter.

and time of the observation, the dwelling unit, the name of the worker, the room the worker was in at the time of the observation, and the substrate he or she was abating, or, if not engaged in a direct lead-paint abatement activity, what other activity was underway (e.g., daily cleanup, set-up, etc.). The data collection form used is included in Appendix E.

All abatement contractors involved in the demonstration were surveyed to obtain the hourly wage rates, position description, and union/non-union affiliation status of each worker. In addition, abatement contractors were asked to supply information on the quantities and unit costs of all materials used on each unit abated and information on the number, types and cost of equipment used at each unit abated for which they were responsible. The data collection forms (Contractor Labor Summary and Materials Use Summary) are included in Appendix F.

2. Abatement Efficacy Data Collection

Measurement of the efficacy of abatement is broadly defined for this purpose to include analysis of data on post-abatement, post-cleanup surface dust lead; on the number of cleanings required to meet surface dust lead clearance standards; on pre- and post-abatement soil lead concentrations; and on the amount of hazardous waste generated.

Surface dust lead measurements were taken after abatement and final cleanup. The measurements were made using wipe tests on the floor, on one window sill and on one window well in each room in which abatement activity had been undertaken. If the clearance standards for surface dust lead were not met after final cleanup, the unit was cleaned again and the wipe tests repeated up to three times, or until final clearance was met. The number of cleanings, and wipe tests, was recorded for each unit in the demonstration.

Two soil samples were taken on each side of each unit in the demonstration both before and after abatement. These samples were analyzed for soil lead concentrations.

All waste generated on sites where hazardous waste disposal regulations were applicable was subjected to extraction procedure (EP) toxicity tests. Using the results of those tests, the quantity of hazardous material was determined for each dwelling unit.

In addition to these well-defined data collection activities, a complete log on the abatement process, noting problems encountered and all substitutions of one abatement method for another when the latter proved infeasible, was maintained for every unit in the demonstration. This log of the hands-on experience of abatement has been used to support the general conclusions on the relative efficacy of different methods of abatement presented in Chapter VI below.

3. Worker Protection Assessment Data Collection

Three kinds of data were collected to support findings on the effectiveness of worker protection safeguards during the demonstration. First, one area air sample was taken in each unit every day, in a room or area in which abatement activity was taking place. Second, one personal breathing zone air sample was taken for each abatement worker every day that abatement was underway. The third set of data collected was blood lead level data, which were obtained for each worker before he or she commenced work and repeated as many times as was required by the NIBS Guidelines.

The complete text of the research design, detailing the objectives of the demonstration, the design of the demonstration, and the data collection process, is included as Appendix C of this report.

III. TESTING FOR LEAD-BASED PAINT

The original design of the lead-based paint testing program for the demonstration recognized the evolving nature of the testing protocols to be utilized. In fact, the Congressional statute calling for the demonstration states in part that "the most reliable technology available for detecting lead-based paint ...[and] the overall accuracy and reliability of laboratory testing of physical samples, portable x-ray fluorescence (XRF) machines, and other available testing procedures" was yet to be determined. With these points in mind, the testing program was designed to be flexible and capable of being revised as additional knowledge and results of the testing system became available. The testing results from the demonstration, presented in this chapter and other sections of this report, provided not only the "abate/do not abate" determination for each substrate in the dwelling units, but also substantial data for use in the analysis of the different testing methodologies. In addition to *in situ* lead-based paint identification, baseline lead levels were determined through the sampling and analysis of airborne dust and soil in an effort to observe and document the effect, if any, that lead-based paint abatement activity might have on the surrounding environment. Much of the data has been forwarded to HUD for use in other testing-related research.

A. <u>The Testing Program</u>

The initial phase of the testing effort was to prepare a complete substrate inventory. A substrate is defined as a material that is coated, usually composed of wood, plaster, or metal, including items such as doors, window trim, walls, baseboards, etc. An inventory form that recorded substrate type, substrate quantity, room type and coating grade and condition was completed for each room and for the exterior of each dwelling unit. A sample inventory form and the corresponding coding system are shown in Appendix G.

Three hundred seventy dwelling units were offered by HUD for testing and abatement in the demonstration, using age as a benchmark for the likelihood of finding lead-based paint. Of these, 304 were inventoried. The balance were rejected for use in the demonstration, primarily due to the unacceptable condition of the substrates within the units. In some cases, factors such as size or location eliminated units from consideration.

The inventory was conducted in the spring of 1989 by a two-member Contractor team, which entered the appropriate codes for each substrate in each room and for the exterior of the 304 dwelling units.

B. X-Ray Fluorescence (XRF) Testing

The next phase of the testing program was to return to the 304 candidate units and test them utilizing the portable XRF analyzers. The XRF testing was undertaken using the NIBS Guidelines protocols, stressing the use of trained, qualified operators; calibration and warm-up procedures; and the taking of baseline readings for all substrates. All substrates in the candidate units were tested with XRF systems, with the exception of substrates on which XRF systems physically could not be utilized due to size or surface irregularity, or on materials not conducive to XRF testing. In the 172 units abated for the demonstration, 16,812 substrates were tested (Table III-1). The number of substrates identified to have lead values greater than or equal to 1.0 mg/cm^2 (the threshold set forth in the NIBS Guidelines) was 3,594, or 21.4% of all substrates tested in the 172 units abated. A summary of XRF testing results is found in Table III-1.

Table III-1

XRF TESTING RESULTS

XRF Value	Number of Substrates Tested: For all 304 Units Tested	Number of Substrates Tested: For the 172 Units Abated
<0.2 mg/cm2	16,667 (62.3%)	10,000 (59.5%)
$\geq$ 0.2 mg/cm^2 or $\leq$ 1.8 mg/cm^2	6,237 (23.3%)	3,942 (23.4%)
>1.8 mg/cm^2	3,854 (14.4%)	2,864 (17.0%)
TOTAL SUBSTRATES	**26,758 (100.0%)**	**16,812 (100.0%)**
<1.0 mg/cm^2	21,895 (81.8%)	13,218 (78.6%)
$\geq$1.0 mg/cm^2	4,863 (18.2%)	3,594 (21.4%)
TOTAL SUBSTRATES	**26,758 (100.0%)**	**16,812 (100.0%)**

XRF results were collected utilizing two teams to test each unit. Each team was comprised of an experienced XRF technician and a "scribe." All substrates listed on the inventory form in the 304 candidate dwelling units were tested by XRF methods when physically feasible.

The testing of substrates by means of XRF analyzers was a multi-step process. The initial step, carried out for each candidate unit, was the calibration of the XRF machine. This was accomplished by taking a set of readings on each of three coating-free substrates -- wood, plasterboard, and concrete. Following the establishment of the baseline readings, every possible substrate from the completed inventory form was tested. First, the operator chose a flat surface at least 3" square on which to place the shutter of the XRF analyzer. The analysis of the coating performed by the XRF analyzer took an average of 45 to 60 seconds per substrate. It resulted in a direct digital reading that was a weighted average of three intermediate readings, automatically generated by the XRF microprocessor. The values reported by the XRF were transcribed onto the inventory form along with baseline readings established for each dwelling unit. A complete computer data base was generated for each of the 304 candidate dwelling units from the inventory forms generated in the field.

C. Atomic Absorption Spectrometry (AAS) Testing

Preliminary selection of units to be abated was made from the XRF data. As a result, the final phase of the testing program, the AAS sampling and analysis phase, was performed only on those units for which abatement was planned. Initially, AAS sampling and analysis was proposed only where the XRF could not be used or where XRF results fell between 0.5 and 1.5 mg/cm^2. The initial demonstration requirement to utilize AAS testing to confirm the XRF results in the lower range of 0.5 to 1.5 mg/cm^2 stemmed from the manufacturer's specified confidence interval. However, during the testing phase of the demonstration, further research was underway regarding the reliability of the XRF analyzer. In consultation with the National Institute of Science and Technology (NIST), it was determined that further testing with AAS should be utilized to insure a more accurate selection of the substrates requiring abatement in the lower range of XRF results. It was, therefore, determined that all XRF readings between 0.2 mg/cm^2 and 1.8 mg/cm^2 would require back-up AAS testing. The follow-up testing program utilizing AAS procedures was implemented in all initially proposed units, and expanded the number of substrates to be tested by AAS from approximately 2,000 to 5,828 (see Table III-2).

Table III-2

AAS TESTING RESULTS

Number of Substrates Tested by AAS

AAS Value	All Units Tested	All Units Abated
< 1.0 mg/cm^2	5,036 (86.4%)	4,332 (87.5%)
$\geq$ 1.0 mg/cm^2	792 (13.6%)	619 (12.5%)
TOTAL SUBSTRATES	**5,828 (100.0%)**	**4,951(100.0%)**

The AAS sampling and laboratory processes are described in the Quality Assurance Plan for Collection and Analysis of Field Lead Testing, Laboratory Lead Analysis and Documentation (Appendix H). Fundamentally, the sampling was performed by chipping or scraping a 1/2" x 1/2" area of the substrate coating and placing it in a plastic bag for transport to the laboratory. Care was taken to obtain all of the coating and a minimal amount of substrate, if any.

As part of this secondary testing phase, three other important functions were performed by the teams, usually comprised of three persons.

The first of these functions was the retesting of certain substrates that were reported to have XRF values outside an anticipated range with respect to like substrates, referred to as outliers. For example, if testing in a room containing four homogenous (identically coated) walls resulted in three XRF values below 1.0 mg/cm^2, and one value above 1.0 mg/cm^2 (the outlier), a confirmatory XRF test was conducted on the "outlier" wall to confirm or negate the initial XRF reading.

A second function was the breakdown and retesting of some substrate systems that had been homogenized for the XRF testing program. For example, a quality control review of XRF data might indicate that a porch system was only tested in three locations as a result of observed homogeneity of the coating. If it was determined that by breaking the porch system down into a greater number of identifiable components, a more accurate assessment would be provided, as many as ten to fifteen components or substrates would be tested by XRF or AAS as appropriate.

Third, substrates determined to require abatement as a result of the XRF testing and all those being AAS sampled were measured in order to determine quantities for bidding purposes. Measurement at this time was more efficient than returning to all units to measure only those substrates determined to require abatement after the AAS analysis. The substrate measurements were combined with the substrate inventory and the testing results in the preparation of the "Part C" section of the abatement contractor bidding package.

D. Test Volume and Results

The number of XRF and AAS samples taken on a per metropolitan area basis are summarized below in Table III-3, Number of Units Tested and Number of XRF and AAS Tests Taken by Research Site. The average number of XRF tests taken per unit inventoried is 92.8. The average number of XRF tests taken per unit abated is 105.0. It should be noted that the number of XRF tests taken for all units inventoried (28,216-Table III-3) and units abated (18,056-Table III-3) is not the same as the number of substrates tested in Table III-1. The difference represents instances in which more than one XRF test was taken on a substrate for purposes of clarification and or confirmation.

Table III-3

NUMBER OF UNITS TESTED AND NUMBER OF XRF AND AAS TESTS TAKEN BY RESEARCH SITE

	Denver	Birmingham	Indianapolis	Baltimore/ Washington	Seattle/ Tacoma	All Cities
Units Made Available for the Demonstration	104	46	83	83	54	370
Units Inventoried	97	37	53	71	46	304
XRF Tests Taken	7,620	3,911	4,350	7,367	4,968	28,216
AAS Tests Taken	1,525	759	963	1,778	803	5,828
Units Abated	57	23	34	32	26	172
XRF Tests Taken	5,319	3,003	3,461	3,137	3,136	18,056
AAS Tests Taken	1,468	637	963	1,205	678	4,951

The average number of substrates tested by XRF and/or AAS per unit is 94.9 for all units inventoried and 107.3 for all units abated (derived from figures, Table III-4). The number of substrates abated, based on an abatement threshold of 1.0 mg/cm^2, is 3,663 (19.8%) of the 18,456 (100.0%) substrates tested by XRF and AAS methods in the 172 units that were abated. Table III-4, Number of Substrates to be Abated by Research Site, provides information regarding total number of substrates tested and those substrates identified as having a lead content greater than 1.0 mg/cm^2 for all units abated, on a per metropolitan area basis. It should be noted that the threshold for abatement, within the State of Maryland was 0.7 mg/cm^2 (0.5 mg/cm^2 for AAS testing). It is interesting to note that of the 3,555 substrates tested in Indianapolis, 487, or 13.7%, were identified to be above the abatement threshold compared to Baltimore/Washington, in which 965, or 27.8%, of the 3,465 substrates tested were identified to be above the 1.0 mg/cm^2 threshold.

Table III-4

NUMBER OF SUBSTRATES TO BE ABATED BY RESEARCH SITE

	Denver	Birmingham	Indianapolis	Baltimore/ Washington	Seattle/ Tacoma	All Cities
Substrates Tested (All inventoried units)	7,999	3,815	4,444	7,864	4,717	28,839
Substrates Tested (All abated units)	5,683	2,805	3,555	3,465	2,948	18,456
Substrates with a lead content greater than 1.0 mg/cm^2 (All abated units)	1,214	411	487	965	586	3,663

E. Lead-in-Soil Testing

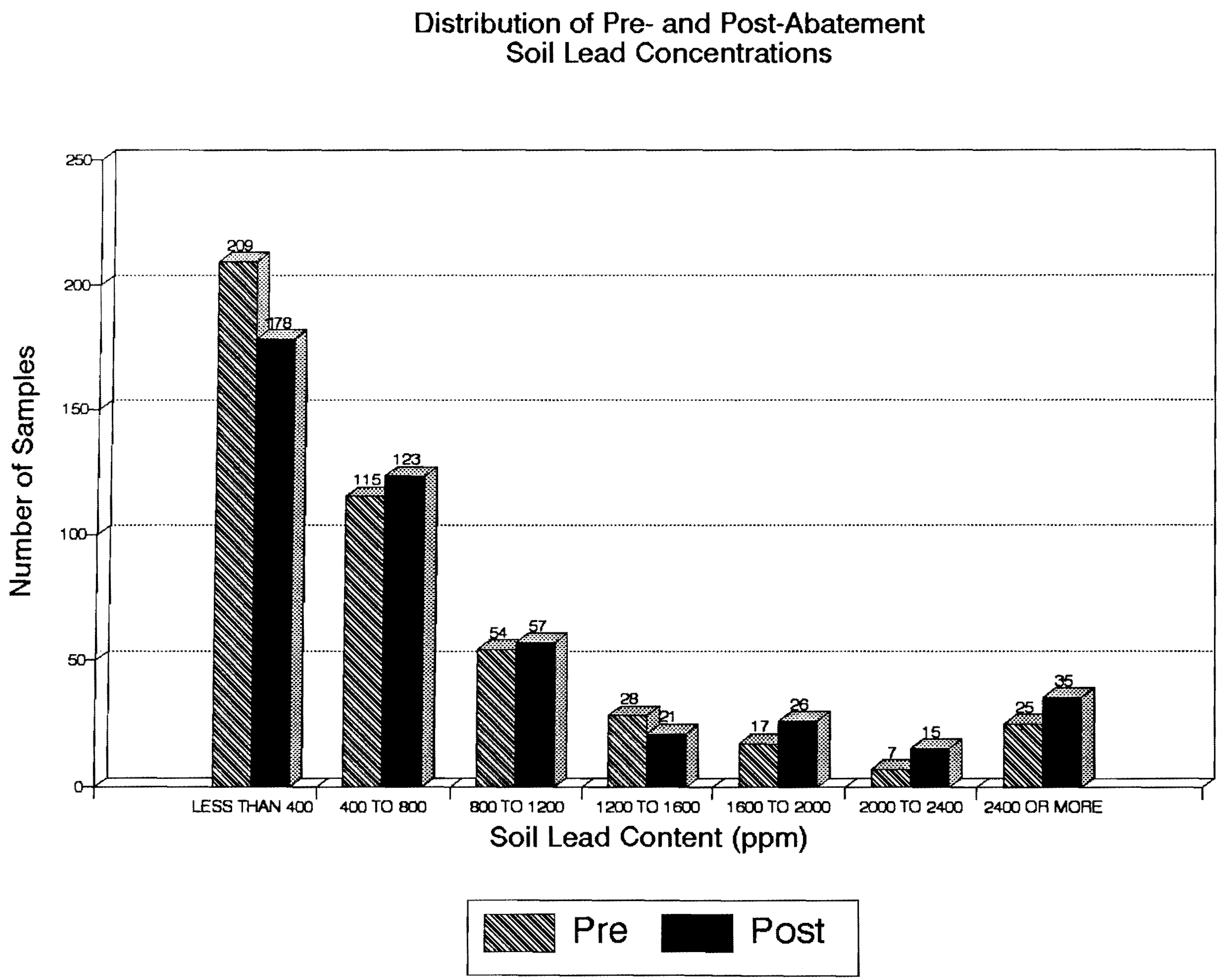
In addition to testing for lead-based paint on interior and exterior substrates, lead-in-soil testing was also conducted. Pre-abatement soil samples were taken at 152 dwelling units initially selected for abatement and post-abatement samples were taken upon completion of all abatement activities in 160 dwelling units. A series of samples was collected approximately one to three feet from the base of each exterior wall of the dwelling unit. Each series contained a total of six soil samples, five of which were collected from locations evenly distributed along the length of the wall. These five samples were then combined to make a composite (the sixth sample) which was then analyzed for lead content.

Because some dwelling units initially selected for abatement were substituted with replacement units, a total of 455 paired (pre- and post-abatement) samples were collected to represent 130 dwelling units, an average of 3.5 paired samples per unit. These samples were all analyzed for lead content of the soil.

The mean value of the soil lead content across all samples was 755.0 ppm before abatement and 867.5 ppm after abatement. The difference of 112.5 ppm between the mean post-abatement and mean pre-abatement soil lead concentration is statistically significant at the 99% level. Absent any other factors which might have contributed to this change there can be little doubt that the lead-based paint abatement work increased the lead content of the soil in the immediate vicinity of the properties in spite of considerable efforts to contain the dust through the use of contaiment procedures outlined in the NIBS Guidelines. The frequency distribution of the pre- and post-abatement lead concentrations is presented in Table III-5.

The pre- and post-abatement differences in soil lead concentrations were analyzed to determine if the Unit Abatement Strategy influenced the observed change in soil lead concentrations. There was some evidence of a statistical relationship between the Unit Abatement Strategy and increases in soil lead greater than 250 ppm. Units abated under the Hand-Scraping and Chemical Strategies were most likely to experience soil lead increases of over 250 ppm, but the differences between the different strategies was not statistically significant at the 5% level.

TABLE III-5



Distribution of Pre- and Post-Abatement
Soil Lead Concentrations
Number of Samples
250
200
150
100
50
0
209
178
115
123
54
57
28
21
17
26
7
15
25
35
LESS THAN 400
400 TO 800
800 TO 1200
1200 TO 1600
1600 TO 2000
2000 TO 2400
2400 OR MORE
Soil Lead Content (ppm)
Pre
Post

IV. WORKER PROTECTION AND PERSONAL EXPOSURE MONITORING

This chapter presents two critical portions of the demonstration. In the first section, the basis for and requirements of the worker protection program are given. The second section summarizes the findings of the lead exposure monitoring undertaken during the abatement process. The application of the full NIBS Guidelines for worker protection was made in order to take a conservative posture for workers on the demonstration; and as stated in the research design, the determination of the impact of alternative worker protection measures and the extent of worker lead exposure on either cost of abatement or blood lead levels was not part of the demonstration's objectives.

A. Worker Protection

The worker protection protocols of the demonstration were derived directly from the NIBS Guidelines, and these Guidelines were incorporated as part of the contracts issued to abatement contractors. In an effort to ensure a complete understanding and accurate interpretation of the NIBS Guidelines, abatement contractors were required to attend a six-hour training session provided by the Contractor. An introduction to the NIBS Guidelines , a discussion of worker protection recommendations from the National Institute for Occupational Safety and Health (NIOSH) generated during the demonstration, and a description of the training program and its related worker medical examinations, the four major aspects of the worker protection program, are provided in the following sections.

1. National Institute of Building Sciences (NIBS) Guidelines

The NIBS Guidelines, developed through a broad-based consensus process, represented current knowledge regarding lead-based paint testing, abatement, cleanup, waste disposal, and worker protection. With regard to worker protection, the NIBS Guidelines were criticized by some as being too conservative; however, the absence of any alternative accepted protocols at the commencement of the demonstration, and the limited scientific knowledge regarding the risk of exposure under various abatement procedures, led HUD to adopt a cautious approach to worker protection.

The NIBS Guidelines call for extensive worker protection procedures during the abatement process. Key points that had an impact on the demonstration are summarized below.

- training of workers on the hazards of lead-based paint
- worker medical monitoring (including blood lead levels) before, during, and after abatement work
- full respiratory protection for workers during virtually all phases of the abatement process from set-up to cleanup
- extensive monitoring of personal exposure to airborne dust lead
- implementation of engineering and work practice controls
- virtually full-time use of protective clothing and shoe covers
- extensive record-keeping regarding worker exposure and surveillance

The complete text of the NIBS Guidelines is included as Appendix I.

2. NIOSH Evaluation

To evaluate the demonstration's implementation of the worker protection protocols of the NIBS Guidelines, NIOSH conducted extensive on-site observations of worker protection and safety and undertook its own program of air monitoring and other environmental testing during the early stages of the abatement effort. The preliminary findings were presented to the contractor in a letter dated February 16, 1990, a copy of which is included as Appendix J. This letter makes interim recommendations in four key areas, including work site practices, personal protective equipment, environmental monitoring, and medical monitoring. Excerpts from the NIOSH letter on each of these key areas appear below. A final NIOSH report on this subject is forthcoming and will provide more definitive findings regarding these worker protection issues.

- With respect to work site procedures:

  ...The use of a two-stage decontamination entry/exit facility to the abatement site should be discontinued; this requirement does not afford any substantial increase in exposure protection to the workers, or the surrounding environment, but does present complicated access to the site by the workers. A designated area, where no abatement or lead hazard exists, should be identified and utilized to prepare to enter/exit the abatement area. This area would contain hand washing facilities, clean clothes storage, dirty clothes storage, and respirator storage space.

Proper signage should be utilized to warn all who enter the site that lead abatement is occurring on site and that access is restricted, and that eating, drinking, and smoking within the site is not allowed.

Strict attention to proper hygiene practices (hand washing after exiting the house, prior to eating, drinking, smoking, etc.) must be maintained. A designated clean area should be provided for these activities.

Adequate ventilation should be provided when using the heat gun, solvent-based strippers and adhesives, or heating the house with propane or kerosene heaters. Appropriate techniques include negative air machines and/or opening the house up to provide natural ventilation (remove polyethylene from and open the windows). Effective ventilation of the abatement areas should be identified and evaluated to address the second echelon of exposure control (i.e., engineering controls to minimize exposures). The use of in-home heating and ventilation systems as an attempt to improve ventilation of abatement sites does not seem feasible and may lead to contamination of other areas (e.g., ductwork and furnace)...

- With respect to personal protective equipment:

  ...Face shields, impervious aprons or clothing, and appropriate gloves should be used with the caustic strippers.

  The use of gloves for all operations and tasks is not necessary except during chemical stripping.

  Portable eye wash bottles with saline solution, or an eye wash station, should be on-site where chemical strippers are used...

  ...We recommend a change in the requirements for use of respiratory protection and full Tyvek suits for certain operations and tasks. During exterior preparation, chemical stripping with caustic-based strippers, encapsulation/enclosure, interior preparation, and heat gun use on the exterior, the use of half-face cartridge respirators and full Tyvek does not appear necessary...[1]

  ...We recommend the continued use of proper respiratory protection during heat gun use on interior areas which are small and/or not well ventilated, during the use of solvent-based strippers, when removing carpet (whether moistened or not), and during any technique which has not been shown by air monitoring to have minimal (less than 15 ug/cubic meter) to no lead exposure potential...

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[1]NIOSH indicated that subsequent review of environmental data may lead to more stringent protective clothing and respiratory protection when chemical stripping is done.

- With respect to environmental monitoring:

  ...Personal breathing zone and area air monitoring for lead should be continued for each abatement technique and the variety of associated tasks until the demonstration project is completed. A provision for follow-up surface dust sampling for lead should be conducted, after the clearance sampling, to determine if abatement procedures have been fully effective. The Baltimore city study indicates certain techniques may not provide complete lead abatement over an extended period of time after re-occupancy.

  Care and attention to detail should be stressed to the field industrial hygienists, especially concerning documenting details about sample collection and variations in observed work practices...

- With respect to medical monitoring:

  ...Regardless of any changes in work practices or equipment, biological monitoring should continue to be performed at least as frequently as currently practiced in this project.

  If there are changes in process or control measures (e.g., the elimination of respiratory protection on some tasks) we recommend reverting to the beginning of the biological monitoring protocol and obtaining follow-up blood lead levels at one month intervals. Similarly, a baseline and monthly level should be obtained if workers return to abatement work after a hiatus of a few to several months. If a worker's blood lead level increases by 10 ug/dl or more, factors contributing to the increase should be identified. Work practices and personal hygiene practices should be reviewed with the worker.

  Consideration should be given to reinstituting erythrocyte or zinc protoporphyrin testing. Theoretically, this test is an indicator of longer-term effects of lead exposure, though it is not truly specific to lead. Its usefulness in the context of these workers with relatively low levels of exposure has not been tested, so if protoporphyrin testing is restarted, it should be done with a clear plan to evaluate its utility. Zinc protoporphyrin (ZPP) testing is a component of the required testing mandated by the OSHA lead standard for general industry...

Each of the recommendations listed above was carefully considered by the Contractor. In situations where reductions to the worker protection protocols were permissible, the abatement contractors were given the option for implementation. Field observations indicate that, as a rule, these changes were made except for those pertaining to respiratory protection and full body protective suits. The abatement contractors did not, generally, change their directions to their workers for respiratory protection and full body protective suits because 1) they wanted to be conservative with respect to this issue; and 2) they perceived the change in direction would be difficult to monitor and control under conditions where multiple abatement activity was being conducted on site or by one individual. Because the NIOSH recommendations included more stringent worker protection in some areas, and reductions in others, no discernable change in costs could be directly attributed to their implementation.

3. Development of Training Program

The Contractor sought to protect the abatement contractors by providing a comprehensive approach to training. This approach utilized the NIBS Guidelines, public health references, and the State of Maryland Department of the Environment Regulations (Title 26, Subtitle 02, Occupational, Industrial, and Residential Hazards, Section II, Health and Safety Training). The reason for using Maryland State regulations was that, of the areas in which the demonstration was conducted, only Maryland had regulations governing the development and utilization of a worker protection training program.

Prior to its implementation, the training program was presented to the Contractor team and key HUD officials, after which it was submitted to both the State of Maryland and HUD for review and approval.

Each abatement contractor employee was required to attend the six-hour training session and to pass a final examination on the subject matter presented. Specifically, the training addressed the following important issues.

- Worker Right-to-Know: Each employee, per U.S. Occupational Safety and Health (OSHA) Hazard Communication Standard (29 CFR 1910.1200), was advised of the hazards to which he/she would be exposed, the precautions he/she should take, and the sources of information he/she could access during the abatement of lead. Employees were also advised of their rights to medical records, exposure records and any company studies.

- Health Effects: Types of blood lead exposure tests, routes of exposure, effects of elevated blood lead levels, signs and symptoms of lead poisoning, medical treatment and diets, conditions for medical removal from the job, and conditions for medical referrals were discussed.

- Personal Hygiene: Personal hygiene practices were stressed during the training and throughout the demonstration. Personal hygiene practices discussed included: prohibition of smoking, eating, drinking, chewing gum or tobacco, and the application of cosmetics in work areas; proper use of decontamination chambers; washing of hands and face; high efficiency particulate accumulator (HEPA) vacuuming of protective clothing before leaving the work area; and additional lead contamination prevention measures.

- Routes of Exposure and Potential Levels: Each employee learned that the two primary routes of exposure to lead are inhalation and ingestion. The use of respirators, body suits and proper personal hygiene was re-emphasized as the method of reducing lead exposure. Additional topics of discussion included measures to reduce exposure of family members or the public to lead and the effects of lead on all persons, especially children, pregnant women and women of child-bearing age.

- Use of Protective Clothing and Equipment: Employees were instructed in the availability and usage of protective clothing and respiratory equipment. Additional areas of concentration included proper procedures for dressing and undressing; and use of gloves, facial protection, shoe coverings, and eye protection.

- Engineering and Work Practice Controls: The abatement contractor was advised of the need for proper planning and scheduling. Items such as set-up, assignment of personnel, purchase of equipment and materials, daily cleaning, control of debris and lead dust, limited access to units and record-keeping were primary issues discussed during this part of the training.

- Other Health and Safety Considerations: General construction safety requirements were reviewed. This involved issues such as safe use of ladders and scaffolding, fire hazards, electrical safety, heat stress and potential hazards that could result from improper use of equipment and exposure to carbon monoxide, solvents, other potentially toxic compounds and caustic chemicals.

To evaluate the overall effectiveness of the demonstration project, a questionnaire regarding the abatement contractor's participation in the demonstration was developed and distributed by the Contractor. In addition to issues such as cost of materials, hazardous waste, blood monitoring, etc., one of the issues raised in the questionnaire was the value of the training program. The general consensus from the abatement contractors was that the training was valuable, but could have been improved by taking a more hands-on, less technical, approach. Specific comments and concerns from the abatement contractors indicated that training was perhaps too narrowly focused on the hazards of lead and not specific enough with respect to practical application of the various abatement methods. Two of the 16 abatement contractors reported a loss of employees immediately following the training program due to the presentation on lead hazards. Many of the abatement contractors indicated that a demonstration of the various abatement methods would have been more beneficial than the presentation regarding extensive dangers of lead. In addition, several abatement contractors commented that more attention should be given to the proper usage of protective clothing and equipment, particularly respiratory equipment.

A copy of the Lead-Based Paint Abatement Health and Safety Training Manual is included for reference in Appendix K.

4. Medical Examinations, Blood Tests, and Respiratory Requirements

The training program was accompanied by stringent medical examinations, blood tests and respiratory requirements. Each abatement worker was contractually required to have a complete medical examination and to obtain a baseline blood lead level. The Contractor facilitated these measures by providing pre-selected medical clinics in each metropolitan area and a central laboratory for blood lead analysis.

The medical requirements were as follows:

- Obtain a detailed work and medical history of each employee.
- Conduct a thorough medical examination including hematologic, gastrointestinal, renal, cardiovascular and neurological systems. Since respiratory protection was required, each employee was also given a pulmonary examination that included a spirometry test and, if doctor ordered, chest X-rays.
- Collect and analyze a blood sample to determine the baseline blood lead level, hemoglobin and hematocrit level, red cell indices, peripheral smear morphology, blood urea nitrogen, and serum creatinine. A routine urinalysis was also performed.

The demonstration protocols called for blood lead monitoring to be conducted prior to abatement, at least every two months during the first six months of the abatement, and at the end of the abatement. If, during these tests, an employee had a blood lead level of 30 micrograms per deciliter (ug/dl) or greater, he/she was either not allowed to commence work, or was removed from the abatement. It should be noted that only the pre-abatement blood lead monitoring was fully implemented. The turnover of workers, the extended duration of the abatement work, and the lack of diligence by the abatement contractors prevented full application of two-month and post-abatement worker monitoring. The Personal Exposure Monitoring section of this chapter contains the details of the results of the blood lead monitoring.

Each abatement contractor was required to have a respiratory protection program in place per OSHA 29 CFR 1910.134. Each employee was trained in the use of his/her respirator and was fit-tested for respirator use. The daily inspection, cleaning, and replacement of respirator cartridges was discussed and demonstrated.

B. Personal Exposure Monitoring

Worker exposure monitoring during the abatement work in the demonstration was performed by collecting at abatement sites personal breathing zone and area air samples that were then tested for lead content. Analysis of the exposure and blood lead data sheds light on the extent of the hazards to which abatement workers would be exposed absent respiratory protection and on the way hazards from airborne lead vary with the methods of abatement employed. The findings of the demonstration imply that the worker protection protocols were successful. However, NIOSH is currently analyzing the data collected during the demonstration and will provide a more comprehensive assessment.

1. Exposure Monitoring Findings

Observations on the abatement activities underway during the personal and area air sample collection were recorded and are used in the analyses presented below. Because of the research interest in examining the relationship between the methods of abatement used and the level of airborne lead, the air samples were not used to construct full shift, time-weighted averages (TWA). During a full shift, several different methods of abatement might have been employed. For the purposes of presentation of results, the standards of 30 micrograms per cubic meter (ug/m^3) and 50 ug/m^3, which generally apply to full-shift, TWA exposures have been used where appropriate.[14] It should be noted, however, that the air sample results reported here are not directly comparable to full-shift, TWA exposures, because the sample times were significantly shorter than eight hours. However, since the samples were collected during work periods, it is assumed here that the eight hour TWA exposures would be similar or lower, as breaks or other periods of reduced action were not sampled.

[14]The 30 ug/meter^3 standard is referenced in the NIBS Guidelines and is embodied in the Maryland Occupational Safety and Health Standard for Occupational Exposure to Lead in Construction Work (COMAR 09.12.32) and in the regulations of Massachusetts Division of Industrial Safety (454 CMR).

The distribution of the personal and area air sample values is presented in Table IV-1 for all readings taken during the demonstration. Approximately 5.9% of the personal air samples and 3.8% of the area air samples had a lead content over the 50 ug/m^3 levels, and 9.4% of the personal air samples and 6.1% of the area air samples had lead content over the 30 ug/m^3 level. Over 80% of the combined numbers of all air samples, both personal and area, showed airborne lead levels below 10 ug/m^3.

Air samples were analyzed to determine whether or not the Unit Abatement Strategy employed was influential in the level of airborne lead during abatement. It will be apparent from Tables IV-2 and IV-3 that the Unit Abatement Strategy does make a difference to the level of airborne lead. Air samples taken in units assigned to the Hand-Scraping with Heat Gun Strategy are considerably more likely to exhibit values over 30 ug/m^3 and 50 ug/m^3. The Replacement Unit Abatement Strategy, initially thought to be a high dust generator, and the Encapsulation Unit Abatement Strategy initially thought to be a low dust generator, appear to generate the least airborne lead, with only around 4% of the personal air samples exceeding 30 ug/m^3. Around 10-12% of the personal air samples from units assigned to the Enclosure and Chemical Strategies exceeded 30 ug/m^3.

Tests of the hypothesis that the levels of airborne lead, both personal and area, are statistically independent of the Unit Abatement Strategy employed are rejected both for the area air samples and, even more strongly, for the personal air samples.

Table IV-1

DISTRIBUTION OF PERSONAL AND AREA AIR SAMPLE VALUES FOR ALL SAMPLES TAKEN

Airborne Lead in ug/m³	Type of Sample: Personal	Type of Sample: Area
< 5	906 (64.7%)	922 (74.8%)
5 - 10	196 (14.0%)	126 (10.2%)
10 - 15	65 (4.6%)	52 (4.2%)
15 - 20	58 (4.1%)	31 (2.5%)
20 - 25	29 (2.1%)	15 (1.2%)
25 - 30	16 (1.1%)	10 (0.8%)
30 - 35	10 (0.7%)	9 (0.7%)
35 - 40	18 (1.3%)	8 (0.6%)
40 - 45	15 (1.1%)	8 (0.6%)
45 - 50	6 (0.4%)	5 (0.4%)
> 50	82 (5.9%)	47 (3.8%)
ALL	1401 (100.0%)	1233 (100.0%)

Table IV-2
DISTRIBUTION OF PERSONAL AIR SAMPLE VALUES BY
UNIT ABATEMENT STRATEGY EMPLOYED

Unit Abatement Strategy*

Airborne Lead in ug/m³	Encapsulation	Enclosure	Chemical	Hand-Scrape w/ Heat Gun	Replacement
< 30	301 (96.2%)	114 (88.4%)	334 (89.5%)	257 (82.6%)	240 (95.6%)
30 - 50	5 (1.6%)	8 (6.2%)	16 (4.3%)	13 (4.2%)	7 (2.8%)
> 50	7 (2.2%)	7 (5.4%)	23 (6.2%)	41 (13.2%)	4 (1.6%)
ALL	313 (100.0%)	129 (100.0%)	373 (100.0%)	311 (100.0%)	251 (100.0%)

Chi-square: 54.0 Degrees of Freedom: 8 Significance 0.0000

Table IV-3
DISTRIBUTION OF AREA AIR SAMPLE VALUES BY
UNIT ABATEMENT STRATEGY EMPLOYED

Unit Abatement Strategy*

Airborne Lead in ug/m³	Encapsulation	Enclosure	Chemical	Hand-Scrape w/ Heat Gun	Replacement
< 30	240 (96.8%)	111 (96.5%)	324 (94.2%)	230 (86.1%)	225 (97.4%)
30 - 50	1 (0.4%)	1 (0.9%)	10 (2.9%)	13 (4.9%)	4 (1.7%)
> 50	7 (2.8%)	3 (2.6%)	10 (2.9%)	24 (9.0%)	2 (0.9%)
ALL	248 (100.0%)	115 (100.0%)	344 (100.0%)	267 (100.0%)	231 (100.0%)

Chi-square: 40.9 Degrees of Freedom: 8 Significance 0.0000

*Because abrasive removal was deemed infeasible, sufficient statistical data could not be generated; therefore, this method does not appear in this table. However, the data collected suggest that exposure levels for abrasive removal are higher than all other techniques.

To further examine the relationship between airborne lead and abatement method, air samples were categorized by the method of abatement (activity) underway at the time the air sample was taken. This analysis is different from the comparison of Unit Abatement Strategies presented in Tables IV-2 and IV-3 above. These activities were then recoded to identify the method of abatement employed. In Table IV-4, the distribution of personal air sample values by method of abatement use, as opposed to Unit Abatement Strategy, is shown. Hand-scraping using a heat gun again appears to be a high generator of airborne lead, with almost 17.5% of the personal air values in excess of 30 ug/m^3.

Table IV-4

DISTRIBUTION OF PERSONAL AIR SAMPLE VALUES BY METHOD OF ABATEMENT IN USE

	Method of Abatement*				
Airborne Lead in ug/m^3	Encapsulation	Enclosure	Chemical	Hand-Scrape w/ Heat Gun	Replacement
< 30	70 (100.0%)	47 (95.9%)	267 (91.8%)	297 (82.5%)	104 (94.5%)
30 - 50	0 (0.0%)	0 (0.0%)	11 (3.8%)	21 (5.8%)	4 (3.6%)
> 50	0 (0.0%)	2 (4.1%)	13 (4.5%)	42 (11.7%)	2 (1.8%)
ALL	70 (100.0%)	49 (100.0%)	291 (100.0%)	360 (100.0%)	110 (100.0%)

Chi-square: 35.9 Degrees of Freedom: 10 Significance 0.0001

*Because abrasive removal was deemed infeasible, sufficient data could not be generated; therefore, this method does not appear in this table. However, the data collected suggest that exposure levels for abrasive removal are higher than all other techniques.

Encapsulation, replacement, and enclosure abatement methods do not appear to generate much airborne dust lead. Only eight samples out of a combined 159 samples (5%) for enclosure and replacement had airborne lead values over 30 ug/m^3. All 70 samples for the encapsulation method had values less than 30 ug/m^3. The hypothesis of statistical independence between airborne lead and the method of abatement in use was strongly rejected.

2. Negative Air Control

The demonstration was also designed to assess the effectiveness of using "negative air control" equipment during the course of abatement for units assigned to the Replacement and Hand-Scraping Unit Abatement Strategies. The effectiveness of negative air in reducing airborne lead in both personal and area air samples was examined. For units assigned to the Replacement Strategy, there were very few instances of personal or area air samples exceeding 30 ug/m^3, whether or not negative air was employed. Of the personal samples six out of 126 cases where negative air was not employed exceeded 30 ug/m^3 and five out of 125 cases where negative air was employed exceeded 30 ug/m^3. Of the area samples, five out of 133 samples where negative air was not employed exceeded 30 ug/m^3, while only one out of 98 samples where negative air was employed exceeded this level. The findings for the effectiveness of negative air in reducing airborne lead under the Replacement Strategy are that it was not statistically significant (p values of 1.00 and 0.38 for personal and area samples, respectively).

The findings on the effectiveness of negative air when Hand-Scraping with a Heat Gun is the Unit Abatement Strategy are different. As noted above, hand-scraping was found to generate the highest levels of airborne lead of all abatement strategies with 17.6% of all personal samples and 13.9% of all area samples exceeding 30 ug/m^3. Under this strategy, 21 out of 151 personal samples with negative air (13.9%) exceeded 30 ug/m^3, while 33 out of 160 personal samples without negative air (20.6%) exceeded this level (p value: 0.16). Of the 121 area samples with negative air, 10 (8.3%) exceeded 30 ug/m^3, while 27 of the 146 samples without negative air (18.5%) exceeded this level (p value: 0.03).

These results suggest that the use of negative air is probably not warranted if replacement of substrates is the primary method of abatement. On the other hand, if hand-scraping with a heat gun is the primary method of abatement, there is evidence that negative air can reduce the level of airborne lead. The evidence is stronger for the area samples than for the personal samples.

3. Blood Lead Monitoring

Monitoring of blood lead (PbB) levels was undertaken as part of the demonstration to determine what impact the worker protection protocols adopted by the Contractor had and to ensure the safety of the abatement contractor personnel. Prior to the commencement of any abatement activity, abatement contractor personnel were required to undergo a complete physical examination and blood lead level analysis. The pre-abatement PbB levels were reviewed by the Contractor to ensure that background PbB levels did not exceed 30 micrograms per deciliter (ug/dl), the level at which abatement contractor personnel were excluded from the demonstration. Abatement contractor personnel were directed to be tested every two months during abatement activity, and once upon completion of abatement work to ensure that an increase in PbB levels had not occurred. Implementation of this program was difficult due to abatement contractor's loss of personnel. Abatement contractors were periodically notified that blood testing was due. In fact only 86 of the 237 abatement workers receiving initial blood tests had one or more follow-up blood tests. It was anticipated that throughout the demonstration, any increase in blood lead would result in a field coordinator review of the abatement contractor's work practices with the abatement contractor field superintendent.

Of the 237 abatement workers receiving initial blood lead tests, only two had blood lead levels of 30 ug/dl or higher. Eighty-six of the workers had one or more follow-up tests during the course of the demonstration (again, this decrease can be attributed to the high employee attrition rate for abatement contractors). Comparison of the initial and first follow-up blood lead levels of the workers who had follow-up tests is one measure of the effectiveness of the worker protection safeguards in force during the demonstration. Of 86 workers who had follow-up tests, 43, or exactly half, were found to have reduced blood lead levels, 15 experienced no change in the blood lead level and 28, or approximately one third, had increases in the blood lead levels. The highest follow-up blood lead level of any of the 86 workers was 22 ug/dl. Given the limited follow-up data, we cannot be certain that no abatement worker had blood lead levels in excess of 30 ug/dl after abatement.

V. THE COST OF LEAD-BASED PAINT ABATEMENT

Estimating the comparative cost of alternative lead-based paint abatement methods was a major objective of the demonstration. It was, of course, recognized that the costs incurred in abating the HUD-owned units would not, on a per dwelling unit basis, be representative of the costs of abating a typical privately owned dwelling unit in the United States. The HUD-owned units were themselves unrepresentative in the sense that they were all vacant, single-family homes that had been acquired subject to FHA mortgage foreclosure procedures and had a high incidence of lead hazards.

These considerations were, however, somewhat irrelevant to the central purpose of the cost estimation component of the demonstration, which was to estimate the costs of abatement on the basis of standard units of measurement, such as per square or linear foot, or per door or window abated. This was to be done for the full range of substrates encountered and for each of the abatement methods. Viewed from this perspective, the HUD-owned units were simply test beds for comparing different methods of abatement on each type of substrate found in residential structures, both in terms of cost and efficacy.

The issue of the universal application of the demonstration findings to the nationwide per square foot or per linear foot cost of abatement was discussed at some length in Chapter II. As noted in the Chapter II discussion of the limitations of the demonstration, the ability to generalize the cost findings of the demonstration is limited not only by the special characteristics of the housing stock used, but also by the strict adherence to the NIBS guidelines, by the fact that abatement was carried out on a stand-alone basis and not integrated with other renovation activity, and because the prices and work practices of relatively inexperienced abatement contractors may not be indicative of the prices and work practices that would prevail if the lead-based paint abatement industry were more developed and experienced. The findings of the cost analysis of the demonstration should be interpreted in light of these caveats.

A. Cost Data and Methods of Analysis

Three sources of data were used in the construction of the cost estimates.

(i) Estimates of the quantities of substrates to be abated. All substrates that tested over the abatement threshold for the lead content of paint were measured in the appropriate units (i.e., square feet, linear feet, number of door systems, etc.). These measurements were used in the bid documents to specify the abatement to be performed and used in the cost analysis to support cost estimates on a per square foot, per linear foot basis.

(ii) Periodic observations were made of the activities of all abatement workers by the on-site industrial hygienist. These observations included a record of the identity of each worker, the location of each worker (unit, room), the activity being undertaken (i.e., chemically stripping window sill, daily cleanup) and the date/time of the observation. Observations were generally made four times during the working day. This information was used to estimate the number of hours worked on each substrate.

(iii) A survey of the abatement contractors was conducted to obtain information on wage rates, material costs and equipment use. The information supplied by the abatement contractors included wage rates for each abatement worker, quantities of materials used and unit prices paid for materials and equipment used, together with equipment cost data. All of the abatement contractors responded to this survey.

Labor costs required to abate lead-based paint hazards were estimated on a per square foot basis (or linear foot or component) for each substrate type, for each method of abatement employed. Estimation of average labor costs per square foot was performed using ratio estimators. For example, the total labor cost (estimated hours x wage rates) expended on removal of lead-based paint from the interior walls using chemical strippers was estimated by multiplying the number of observations of workers using chemical strippers to remove paint from interior walls by the average interval between observations, multiplying hours by hourly wage rates, and totaling the results. This quantity was then divided by the total number of square feet of interior walls on which chemical strippers were used, to obtain an estimate of the average labor cost required to chemically strip an interior wall.[15]

[15]Ratio estimates such as these present a technical problem when it comes to estimating their sampling variance. There is a second-order approximation for the variance that is widely used. Let R denote the ratio estimator:

$$R = \bar{x} / \bar{y}$$

where $\bar{x}$ and $\bar{y}$ respectively denote the sample means of costs and sq. foot for a given substrate and abatement method. Then:

$$S^2(R) = (n\bar{y}^2)^{-1} \left[S^2(x) + R^2 S^2(y) - 2\, R \operatorname{Cov}(x,y)\right]$$

where S^2 and Cov denote the sample variants and covariance respectively (see William G. Cochran, Sampling Techniques, 3rd Edition, Wiley, 1977, page 155).

The classification of worker activities included some that did not identify a specific substrate being abated. These activities included mobilization, set-up, breaks, and cleanup activities. The labor costs of these other activities were regressed on the labor costs of abatement activities incurred under each of the six Unit Abatement Strategies to obtain estimates of the amounts by which the labor costs directly associated with abatement should be marked up to obtain estimates of total labor costs. The constant term in the regression that was statistically insignificant was suppressed to permit full allocation of labor costs to the substrates abated.

Data on materials, prices, and utilization were provided by the abatement contractors for each dwelling unit abated. Average direct materials costs per square foot were then computed by dividing the total costs of materials used in each method (e.g., encapsulants, chemical strippers, replacement substrates) by the total number of square feet abated by that method. The costs of materials that could not be directly attributed to a particular abatement method (e.g., polyethylene sheeting and respirators) were regressed on the number of square feet abated under each of the six Unit Abatement Strategies to obtain estimates of the per square foot costs of other materials. Again the constant term in the regression was suppressed.

The last step in the process involved the computation of overhead and profit for each of the dwelling units. This was done by estimating the potential markup of a contractor relative to his labor and material costs.

The product of this exercise was a set of per square foot, per linear foot, and per window/door cost estimates for each type of substrate for each of the possible methods of abatement.

B. Cost Estimates

The cost estimates are, as noted above, made up of five components:

(1) Direct labor costs of abatement
(2) Indirect labor costs of abatement
(3) Direct materials costs of abatement
(4) Indirect materials costs of abatement
(5) Contractors' overhead and profit

1. Direct Labor Costs

Direct labor costs are defined as those costs that reflect the payment of workers for their time actually spent on lead-based paint containment or removal. They do not include the labor costs associated with set-up, daily cleanup, final cleanup, mobilization, etc., which cannot be directly attributed to particular substrates requiring abatement.

These costs were estimated by estimating the hours spent by all workers on abating a particular substrate, multiplying these estimates by the hourly wage of each worker, and summing across all workers and all substrates of a given type abated by a specific method. This sum was then divided by the total square feet (or linear feet, or number of windows, doors, etc.) of that substrate type abated by the specified method. The estimates can be interpreted as being estimates of the average direct labor costs of abating a given substrate using a given method in the demonstration. The direct cost estimates, together with their standard errors, are presented in Table V-1. For a number of substrate/method combinations, cost estimates are not provided. These cases are either technically infeasible or the estimates are unreliable because there were too few instances of these combinations in the demonstration.

2. Indirect Labor Costs

Indirect labor costs are defined as those costs that cannot be attributable by observation to a particular substrate, such as labor spent on set-up, daily cleaning, etc. To determine how the total indirect labor costs vary with the number of square feet abated and with the method of abatement employed, a regression was run of estimated indirect costs per dwelling unit on the number of square feet abated by each method. The estimated regression equation is:

$$\underset{\text{Labor Costs}}{\text{Indirect}} = \underset{(0.48)}{0.40} * SFREPL + \underset{(0.14)}{0.79} * SFENCAP + \underset{(0.73)}{2.84} * SFHS + \underset{(0.55)}{3.61} * SFCHEM + \underset{(0.25)}{1.42} * SFNC$$

$R^2 = 0.60$ $F = 45.6$ Standard Errors in Parentheses

Table V-1

ESTIMATED DIRECT LABOR COSTS IN UNITS OF MEASUREMENT BY SUBSTRATE TYPE AND BY ABATEMENT METHOD (Standard Errors in Parentheses)

Component Type	Unit**	Encapsulation		Enclosure		Chemical		Hand-Scrape with/Heat Gun		Replacement	
		Abatement Method*									
Interior											
Baseboard	LF	$1.29	($0.29)	–	–	$3.67	($0.72)	1.92	($0.41)	$1.82	($0.60)
Cabinet	SF	3.62	(1.21)	–	–	–	–	9.40	(3.42)	–	–
Ceiling	SF	1.15	(0.44)	1.41	(0.23)	–	–	–	–	–	–
Door	EA	41.18	(6.40)	–	–	40.08	(8.57)	49.17	(9.76)	13.26	(4.69)
Door Frame	LF	1.34	(0.16)	–	–	2.11	(0.33)	2.85	(0.58)	1.34	(0.29)
Shelves	SF	1.33	(0.41)	–	–	5.61	(1.86)	–	–	–	–
Wall	SF	0.98	(0.16)	1.47	(0.18)	–	–	0.58	(0.16)	–	–
Window	EA	34.78	(5.73)	–	–	33.02	(8.32)	41.44	(6.89)	25.59	(5.60)
Window Sill	LF	2.23	(0.44)	–	–	7.72	(2.08)	2.29	(0.55)	2.80	(1.12)
Window Trim	LF	1.47	(0.28)	1.80	(0.09)	1.78	(0.35)	2.31	(0.50)	0.95	(0.24)
Exterior											
Column	SF	–	–	5.25	(2.01)	5.71	(1.81)	–	–	5.30	(2.37)
Door	EA	30.97	(8.48)	–	–	28.15	(10.20)	39.52	(11.36)	38.80	(10.36)
Door Frame	LF	1.69	(0.25)	–	–	1.72	(0.62)	1.86	(0.46)	2.34	(0.96)
Soffits	SF	0.83	(0.22)	1.65	(0.40)	2.11	(0.70)	4.25	(1.18)	–	–
Wall	SF	0.42	(0.08)	0.58	(0.16)	4.97	(1.69)	–	–	–	–
Window	EA	19.10	(3.31)	–	–	37.93	(8.38)	25.66	(5.13)	12.32	(4.85)
Window Sill	LF	1.22	(0.27)	–	–	0.98	(0.43)	3.07	(1.03)	2.76	(1.30)
Window Trim	LF	0.76	(0.13)	1.32	(0.59)	0.75	(0.24)	2.44	(0.59)	0.80	(0.19)

* Because abrasive removal was deemed infeasible, sufficient statistical data could not be generated; therefore, this method does not appear in this table.
**SF denotes "per square foot," LF denotes "per linear foot," and EA denotes "each" (i.e., per door or per window)

where SFREPL denotes square feet abated using the replacement method, SFENCAP denotes square feet abated using the encapsulation method, and so on. The coefficients of these variables have the direct interpretation of the dollar cost of indirect labor per square feet associated with each of these methods.

3. Direct Materials Costs

Direct material costs were estimated separately for each method on a square foot basis. With the exception of windows and doors, the total cost of materials used by a given method (e.g., encapsulants, chemical strippers, heat gun filters/scrapers, wall board/nails, lumber/nails, sandpaper/grinder blades) was divided by the total number of square feet abated using that method of abatement. The total direct materials cost for windows and doors (replacement method only) was estimated simply by taking the average cost of replacement windows and replacement doors. The estimated direct materials costs per square foot and per window and per door (replacement strategy only) are shown in Table V-2.

As before, the coefficient on the number of square feet abated by each method corresponds to the per square foot cost of indirect materials when that method is employed.

4. Indirect Materials Costs

Indirect materials were defined as those materials that are not attributable by observation to particular substrate abatement activities. They include such items as polyethylene sheeting, tape, labels, and disposable protective clothing. The per square foot costs of indirect materials were estimated in the same way that the per square foot costs of indirect labor were estimated. A regression was run of the indirect materials costs used in each unit on the number of square feet abated by each method of abatement. The estimated regression was:

$$\text{Indirect Materials} = \underset{(0.52)}{0.25} * \text{SFREPL} + \underset{(0.06)}{0.35} * \text{SFENCAP} + \underset{(0.30)}{0.38} * \text{SFHS} + \underset{(0.59)}{1.24} * \text{SFCHEM} + \underset{(0.09)}{0.55}\ \text{SFENC}$$

$R^2 = 0.59$ $F = 41.73$ Standard Errors in Parentheses

Table V-2

ESTIMATED DIRECT MATERIALS COSTS AND STANDARD ERRORS PER SQUARE FEET FOR ALL SUBSTRATES BY ABATEMENT METHOD AND PER WINDOW AND DOOR FOR REPLACEMENT METHOD[16]

Abatement Method	Estimated Direct Materials Cost Per Square Foot	Standard Errors
Encapsulation	$0.22	$0.04
Enclosure	0.84	0.16
Chemical	2.05	0.46
Hand-Scraping	0.03	0.01
Replacement (except windows & doors)	3.01	0.92
Replacement windows*	119.66	13.6
Replacement doors*	38.06	9.6

*Measured per substrate rather than per square foot.

5. Abatement Contractors' Overhead and Profit

It was originally planned to estimate abatement contractors' overhead and profit by comparing estimated labor and materials costs incurred on-site with the prices paid for the abatement work. This markup would correspond to the amount abatement contractors received to compensate them for employee fringe benefits, equipment costs and back office expense, as well as profit. When this was done, wide variation was noted in the overhead and profit markups experienced by different abatement contractors on different sites. When averaged across all abatement contractors, the average markup was approximately 84% on the sum of labor and materials costs, which seems to be unusually high and may reflect allowance for contingencies associated with performing

[16]The conversion factors from linear to square feet that were used are: baseboards: 3:1, door frames: 2:1, window sills: 2:1, window trim: 3:1. The conversion factors that were used for windows and doors are : 1 window = 12 sq. ft. and 1 door = 42 sq. ft., based on one side of windows and both sides of doors.

lead-based paint abatement for the first time, as well as training expenses, which were not included in the cost estimates.

For the purpose of preparing the cost estimates presented here, a markup for abatement contractors' overhead and profit of 50% has been used. It is believed that this more closely approximates the overhead and profit percentage that would prevail if lead-based paint abatement were carried out on a routine basis.[17]

6. Total Costs of Abatement by Substrate and by Method of Abatement

Consolidating all five categories of cost discussed above permits estimates to be made of the aggregate costs of abatement, including direct and indirect labor costs, direct and indirect materials costs, and abatement contractors' overhead and profit. These estimates are presented by substrate and by method of abatement in Table V-3.

For the substrates reported, encapsulation is estimated to be the least expensive method of abatement in all but one instance; interior doors, where replacement is estimated to be less expensive. When the costs of encapsulation and enclosure, the two abatement methods that contain rather than remove lead hazards, are compared, enclosure is estimated to cost 68% more for ceilings, 83% more for interior walls, 42% more for interior window trim, 103% more for soffits, 90% more for exterior walls, and 86% more for exterior window trim. While encapsulation was determined to be the least expensive abatement method for window systems, it should be noted that the potential for encapsulation failure is extremely high due to the vulnerability of window systems to abrasive action and environmental factors. The encapsulation abatement method cannot be used on friction surfaces such as window tracks and door jambs where the encapsulation surfaces are subject to failure. For these reasons, encapsulation of window systems is not permitted, and was not performed, in the State of Maryland. As noted earlier, the relative durability of encapsulants versus enclosure systems for most other substrates is not known at this time. It is certainly possible that enclosure

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[17]The comparable overhead and profit percentage for chemical removal of lead-based paint is estimated to be approximately 55% according to data compiled by the R.S. Means Company, Inc., in its publication, *Means Repair & Remodeling Cost Data, Commercial/Residental*, 12th Edition, pp. 158, 159.

Table V-3

ESTIMATED AGGREGATE COSTS PER UNIT OF MEASUREMENT BY SUBSTRATE TYPE AND ABATEMENT METHOD (Standard Errors in Parentheses)

Component Type	Unit of Measurement	Abatement Method: Encapsulation		Enclosure		Chemical		Hand-Scrape w/Heat Gun		Replacement	
Interior											
Baseboard	LF	$2.62*	(0.29)	-	-	$8.96	(0.76)	$4.51	(0.48)	$4.56	(0.70)
Cabinet	SF	7.48*	(1.22)	-	-	-	-	18.97	(3.51)	-	-
Ceiling	SF	3.77*	(0.46)	6.34	(0.38)	-	-	-	-	-	-
Door	EA	147.61	(9.23)	-	-	494.93	(32.47)	278.69	(34.17)	110.81*	(24.01)
Door Frame	LF	3.03*	(0.18)	-	-	8.34	(0.50)	6.71	(0.70)	4.76	(0.60)
Shelf	SF	4.03*	(0.44)	-	-	18.77	(2.00)	-	-	-	-
Wall	SF	3.51*	(0.22)	6.43	(0.36)	-	-	5.75	(0.80)	-	-
Window	EA	76.70*	(6.04)	-	-	173.77	(12.22)	120.72	(11.62)	205.52	(15.62)**
Window Sill	LF	4.36*	(0.45)	-	-	16.75	(2.11)	5.87	(0.67)	6.94	(1.24)
Window Trim	LF	2.89*	(0.28)	4.11	(0.14)	6.13	(0.43)	5.09	(0.57)	3.26	(0.42)
Exterior											
Column	SF	-	-	12.10*	(2.03)	18.92	(1.96)	-	-	13.44	(2.60)
Door	SF	132.30*	(10.78)	-	-	477.03	(32.94)	264.22	(34.66)	149.12	(25.72)
Door Frame	LF	3.56*	(0.27)	-	-	7.76	(0.72)	5.23	(0.60)	6.26	(1.10)
Soffit	SF	3.29*	(0.27)	6.69	(0.50)	13.52	(1.03)	11.25	(1.41)	-	-
Wall	SF	2.68*	(0.18)	5.10	(0.35)	17.81	(1.85)	-	-	-	-
Window	EA	53.18*	(3.82)	-	-	181.12	(12.26)	97.05	(10.67)	205.52	(15.62)**
Window Sill	LF	2.85*	(0.28)	-	-	6.65	(0.57)	7.05	(1.11)	6.88	(1.41)
Window Trim	LF	1.82*	(0.14)	3.38	(0.60)	4.58	(0.35)	5.28	(0.65)	3.04	(0.40)

*Denotes least expensive method.

**The cost for replacing a window, whether interior or exterior, includes the cost for replacing the opposite side of that window.

systems such as wall board may be effective in containing hazards for much longer periods than encapsulants and may therefore be competitive on a discounted future cost basis.

Of the three removal methods, it is apparent that chemical removal is generally not cost-competitive with either hand-scraping with a heat gun or replacement. For baseboards, chemical removal is estimated to cost $8.96 per linear foot, compared to $4.51 for hand-scraping and $4.56 for replacement. This pattern is repeated for most other substrates. Chemical removal is 75% more expensive than replacement for door frames, 347% more expensive than replacement for doors, 44% more expensive than hand-scraping for windows, 185% more expensive than hand-scraping for window sills, and 88% more expensive than replacement for window trim. Chemical removal is, however, probably the only feasible removal method for exterior walls, although it is almost seven times more expensive than encapsulation and 3.5 times more expensive than enclosure for exterior walls.

When the replacement and hand-scraping with heat gun methods are compared in terms of costs, they are frequently found to be quite similar. Replacement is clearly less expensive for interior doors, interior door frames, interior window trim, exterior doors and exterior window trim. Hand-scraping is less expensive for windows if only the interior or the exterior needs to be abated. However, if both interior and exterior need to be abated, the cost of replacement is comparable to the cost of hand-scraping. The cost of replacing an interior window includes the cost of replacing the exterior of that same window, and vice versa. For baseboards, interior window sills, exterior door frames and exterior window sills, the differences in the estimated costs of the two methods are not statistically significant. It should also be noted that, while replacement is 1.5 to two times more expensive than encapsulation for most substrates, it appears to be quite competitive for doors, both interior and exterior.[18]

[18]The cost estimates presented here are all on a "unit" basis, that is to say per square foot, per linear foot, or per system for windows and doors. To estimate the costs of abating lead hazards in a typical dwelling unit, it is necessary to combine these "unit" cost estimates with estimates of the number of square feet or linear feet of each substrate type and the number of windows and doors to be abated. It is also necessary to specify the methods of abatement to be employed.

An average abatement cost per housing unit was developed, based on the average square footage of surfaces with lead-based paint in housing reported in *The Comprehensive and Workable Plan for the Abatement Lead-Based Paint in Privately Owned Housing* and the abatement cost findings of this report. The average costs of abatement are $2,908 per unit for encapsulation and $7,703 per unit for removal. As the Comprehensive and Workable Plan shows (Table 4-7), many units will cost less and some with larger amounts of lead-based paint will cost more to abate. All of the above per unit costs reflect a combination of the least costly methods available within the respective encapsulation and removal strategies, including the use of replacement where appropriate (see Table V-3). As Table V-3 indicates, the least expensive method for all components is generally encapsulation. The exceptions are interior doors, for which replacement is the least expensive method, and windows, where replacement may be preferred because of the difficulty of successful encapsulation. Among the removal strategies, handscraping with a heat gun proved the least expensive method, except for windows and interior doors. For window sills and trim, however, the cost difference between chemical removal and handscraping is minimal.

C. The Cost of Disposing of Hazardous Materials

The cost estimates presented above do not include any costs incurred in the disposal of hazardous materials. In the demonstration, costs associated with the disposal of hazardous materials were incurred at three research sites: Denver, Birmingham, and Seattle/Tacoma. The costs of the waste stream analysis, pick-up and disposal were $9,625 in Denver, $10,221 in Birmingham, and $4,675 in Seattle/Tacoma. Because appropriate authorities in Baltimore/Washington and Indianapolis did not specify more stringent regulations, waste in those cities was treated as non-hazardous under the domestic exception of the Resource Conservation and Recovery Act (RCRA), and disposed of in local landfill sites. It is not within the scope of the demonstration research design to speculate on whether or not waste generated by the abatement of residential lead hazards will be permitted to qualify for the domestic exception from RCRA. Accordingly, the discussion of hazardous waste disposal costs presented here will be confined to an analysis of the cost experience in Denver, Birmingham, and Seattle/Tacoma. Estimates of the number of pounds of hazardous waste per dwelling unit abated were developed by counting the number of bags/barrels of hazardous materials at each dwelling unit and knowing the total weight of disposed hazardous waste in each metropolitan area. On average, 216.7 lb. of hazardous materials were generated per dwelling unit across all three research sites (128.9 lb. in Denver, 517.4 lb. in Birmingham, and 96.9 lb. in Seattle/Tacoma). The average cost of disposal across all three research sites was $1.18 per lb., ($1.31 in Denver, $0.86 in Birmingham, and $3.02 in Seattle/Tacoma) or $255.43 per dwelling unit ($168.86 in Denver, $444.39 in Birmingham, and $292.19 in Seattle/Tacoma). The amount of waste generated was dependent upon the type of substrate to be abated, the Unit Abatement Strategy assigned, the amount of lead-based paint to be removed, and the ability to minimize the contamination of the work site during hazardous waste generation.

The cost of hazardous material disposal was strongly influenced by the Unit Abatement Strategy to which the dwelling unit was assigned. The average volume and cost of hazardous waste disposal per dwelling unit by Unit Abatement Strategy is presented in Table V-4.

Table V-4

AVERAGE VOLUME AND COST OF HAZARDOUS WASTE DISPOSAL BY UNIT ABATEMENT STRATEGY

Unit Abatement Strategy	Average Volume (per house) of Hazardous Materials (lb)	Average Cost (per house) of Hazardous Waste Disposal
Encapsulation	99.2	$117.02
Enclosure	104.5	$123.36
Chemical	436.0	$514.48
Hand-Scraping w/Heat Gun	260.5	$307.42
Replacement	117.5	$138.65
ALL	216.7	$255.43

A further examination of the effects of abatement method on hazardous waste disposal costs was performed using regression analysis in the same way that the influence of abatement method on indirect labor and materials costs was examined. The estimated regression was:

Costs of Hazardous Waste Disposal

$$\text{Costs of Hazardous Waste Disposal} = \underset{(0.10)}{0.05} * SFREPL + \underset{(0.03)}{0.12} * SFENCAP + \underset{(0.17)}{0.13} * SFHS + \underset{(0.14)}{0.99} * SFCHEM + \underset{(0.05)}{0.02} * SFENC$$

$R^2 = 0.56$ $F = 20.0$ Standard Errors in Parentheses

This further confirms the extremely high costs of hazardous waste disposal when chemical methods are used. Based on the limited demonstration experience, an additional $0.99 per square foot would be added to the costs of abatement by on-site chemical stripping.

VI. THE EFFICACY OF LEAD-BASED PAINT ABATEMENT

Aside from determining abatement cost, one of the key objectives of the demonstration was to determine and evaluate the overall usability and effectiveness (or efficacy) of various methods of lead-based paint hazard abatement. At the outset, "efficacy" was narrowly defined by the Research Objectives as:

> *3) To measure the extent of post-abatement lead hazards (measured by wipe tests) and to examine the relationship between post-abatement surface lead dust levels and the methods of LBP abatement employed. The way in which clean-up costs vary with post-abatement surface lead levels will be examined, and soil test data will also be reported.*

However, as presented in this chapter, the term efficacy has been expanded to include not only the final hazard factors (wipe test and cleanup costs) as stated in the objective, but also the practicalities of the abatement methods.

Stated in another way, the demonstration has provided great insight not only into the final dust lead level analysis and the final cost analysis, but also into the logical approach to abatement design. Efficacy considerations must include the contractibility, applicability, and general engineering logic of abatement methods.

This chapter will present the larger picture of efficacy as defined above, outlining key factors observed and evaluated during the demonstration. The chapter begins with a discussion of the visual clearance and final cleaning processes and results of the abatement work. Then, the rates of success and failure of dwelling units in meeting final wipe clearance standards are reported. Finally, the chapter presents the practical findings of the demonstration with regard to each method of abatement's usability, practical application, and ability to get the job done. Ultimately, this chapter, combined with cost findings, will provide a sound basis for the determination of abatement strategies in lead-based paint hazard abatement.

A. Visual Clearance Testing and Final Cleaning

The NIBS Guidelines call for visual clearance inspections of dwelling units after abatement is complete and before units receive final, as opposed to daily, cleaning. Visual inspections were carried out to determine that lead-based paint had either been completely removed from substrates scheduled for abatement or that painted substrates had been effectively covered by encapsulants or enclosure materials, in accordance with sound construction practice and the generic abatement specifications. Abatement contractors were required to correct all items identified by visual inspection before final cleaning commenced.

The need to carry out further abatement after visual inspection occurred most frequently when chemical removal abatement methods were used. In fact, chemical removal often required several applications of chemical strippers before visual clearance standards could be achieved. Hand-scraping with a heat gun frequently required further touch-up work following visual inspection. These problems were most frequently encountered, both for chemical and hand-scraping abatement methods, when the methods were used on ornate or porous wood substrates.

The final cleaning of each dwelling unit was initiated after the visual clearance of abatement work. After all debris and polyethylene sheeting were removed, dwelling units were cleaned, starting at the ceilings and working down the walls to the floors, by vacuum cleaning using a high-efficiency particulate accumulator (HEPA), followed by a wet washing with trisodium phosphate (TSP), followed by another HEPA vacuuming. A washing solution of at least 5-10% TSP was required in accordance with the product manufacturer's instructions. All surfaces including ceilings, walls, floors, window systems, door systems, lighting fixtures and built-in cabinets were cleaned in the process.

Waste disposal was handled in a variety of ways. Large debris from replacement abatement was wrapped in 6 mil plastic and sealed with duct tape before it was removed from the dwelling unit. Other debris was contained in a properly designated storage area until disposal in accordance with State and local regulations was carried out (see Chapter VII). In an effort to minimize the amount of dust lead released into the air, small debris that was generated was sprayed with a fine mist prior to collection. Polyethylene sheeting used to protect the floor from exposure to dust lead and abatement activity, including exposure to caustic strippers, encapsulants, etc., was also sprayed with a fine mist and HEPA vacuumed prior to removal from the dwelling unit.

B. Wipe Test Clearance Results and the Efficacy of Final Cleaning

Abatement of all lead-paint hazards in a dwelling unit will not render the unit safe unless the dust lead is also removed. This dust lead may have been present before abatement or it may have been generated by the abatement process. In either case, dust lead must be removed.

The NIBS Guidelines, having noted the absence of any Federal standards governing the level of lead in house dust, adopted clearance standards for abated dwelling units of 200 ug/ft^2 for floors, 500 ug/ft^2 for window sills and 800 ug/ft^2 for window wells. These standards are used in Maryland and Massachusetts and they were used in the demonstration. Testing was performed in all abated areas by surface wipe sampling using commercial wipes moistened with a non-alcoholic wetting agent. Wipe samples were taken from floors, window wells, and window sills in each abated area. Although the NIBS Guidelines permit smaller numbers of wipe tests when abatement consists exclusively of encapsulation and replacement activities,[19] full wipe testing was performed in all units of the demonstration. Wipe tests were performed after the units had been "final cleaned," but prior to recoating or priming.[20] If the surface dust lead clearance standards were not met, the units were "final cleaned" again and the wipe tests repeated, and so on, up to three cleaning iterations.

The failure rates on the initial wipe tests were 19.3% for floors, 14.2% for window sills, and 33.0% for window wells. Classifying the tests by the Unit Abatement Strategy to which the dwelling unit was assigned makes it clear that the likelihood of passing the various tests is highly dependent on the Unit Abatement Strategy. Looking at the pass/fail rates on initial wipe tests (Tables VI-1, VI-2 and VI-3), the failure rate on floors is seen to have ranged from 12.5% and 13.8% for the Replacement and Encapsulation Strategies, respectively, to 28.8% for the Hand-Scraping Strategies. For window sills, the failure rates ranged from 4.8% (Encapsulation Strategy) to 24.1% (Chemical Strategy) and for window wells from 21.0% (Replacement

[19] Op.cit.,p.57.

[20] The NIBS Guidelines call for the recoating or priming of surfaces prior to clearance wipe samples being taken. In the demonstration, this recoating was not performed until after the surfaces had passed the wipe standards, or until after three iterations of cleaning took place. This allowed for more meaningful data to be collected for the evaluation of the efficacy of a method, and is clearly more conservative in terms of achieving clearance standards.

Strategy) to 45.7% (Chemical Strategy) and 44.5% (Hand-Scraping Strategy). These differences in the influence of Unit Abatement Strategies on the pass/fail outcome are statistically significant for each test, with the Chemical and Hand-Scraping Strategies typically associated with the highest failure rates on each test.

The median number of floors, window sills, and window wells tested in each unit was 7, 5 and 4, respectively. The distribution of the causes of failure for the 114 units that failed the initial tests were:

Floors, Sills, and Wells	24.6%
Floors only	22.8%
Wells only	14.0%
Floors and Well	14.0%
Sills and Wells	9.6%
Floors and Sills	9.6%
Sills only	5.3%
	100.0%

Table VI-1

DISTRIBUTION OF WIPE SAMPLE VALUES ON FLOORS BY CLEARANCE STANDARD (PASS/FAIL) ON INITIAL WIPE TEST BY UNIT ABATEMENT STRATEGY

	Unit Abatement Strategy				
Wipe Sample Value ug/ft^2	Encapsulation	Enclosure	Chemical	Hand-Scrape w/Heat Gun	Replacement
< 200	188 (86.2%)	96 (80.0%)	276 (77.3%)	163 (71.2%)	203 (87.5%)
≥ 200	30 (13.8%)	24 (20.0%)	81 (22.7%)	66 (28.8%)	29 (12.5%)
ALL	218 (100.0%)	120 (100.0%)	357 (100.0%)	229 (100.0%)	232 (100.0%)

Chi-square: 25.1 Degrees of Freedom: 4 Significance 0.0000

Table VI-2

DISTRIBUTION OF WIPE SAMPLE VALUES ON WINDOW SILLS BY CLEARANCE STANDARD (PASS/FAIL) ON INITIAL WIPE TEST BY UNIT ABATEMENT STRATEGY

Wipe Sample Value ug/ft^2	Encapsulation	Enclosure	Chemical	Hand-Scrape w/Heat Gun	Replacement
< 500	157 (95.2%)	78 (91.8%)	173 (75.9%)	124 (75.6%)	137 (92.6%)
≥ 500	8 (4.8%)	7 (8.2%)	55 (24.1%)	40 (24.4%)	11 (7.4%)
ALL	165 (100.0%)	85 (100.0%)	228 (100.0%)	164 (100.0%)	148 (100.0%)

Chi-square: 39.5   Degrees of Freedom: 4   Significance 0.0000

Table VI-3

DISTRIBUTION OF WIPE SAMPLE VALUES ON WINDOW WELLS BY CLEARANCE STANDARD (PASS/FAIL) ON INITIAL WIPE TEST BY UNIT ABATEMENT STRATEGY

	Unit Abatement Strategy				
Wipe Sample Value ug/ft^2	Encapsulation	Enclosure	Chemical	Hand-Scrape w/Heat Gun	Replacement
< 800	75 (74.3%)	45 (76.3%)	95 (54.3%)	61 (55.5%)	79 (79.0%)
≥ 800	26 (25.7%)	14 (23.7%)	80 (45.7%)	49 (44.5%)	21 (21.0%)
ALL	101 (100.0%)	59 (100.0%)	175 (100.0%)	110 (100.0%)	100 (100.0%)

Chi-square: 19.3   Degrees of Freedom: 45   Significance 0.0007

It was noted earlier that units that failed on any of the wipe tests were then "final cleaned" again and retested. Test results were available for the 166 properties that underwent interior abatement (wipe tests were not utilized for units that had exterior abatement only). Of the 166 properties, 124 passed the tests after one or more cleanings and 42 did not pass the tests. Of the 124 that passed, 44 (33.5%) passed on the first test, 42 (33.9%) passed on the second test, 27 (21.8%) passed on the third test, 9 (7.3%) passed on the fourth test, and 1 (0.8%) passed on each of the fifth and sixth tests. Eleven units went beyond three cleaning iterations at the Contractor's discretion; various external factors determined these actions. The ultimate failure rates ranged from 15.2% and 14.3% for units assigned to the Replacement and Encapsulation Strategies, respectively, to 35% for units assigned to the Enclosure Strategy. The Unit Abatement Strategy did not, however, appear to influence the number of cleanings required for the 124 units that passed the tests at some point.

After three final cleaning iterations, those units that still had a point of failure were addressed by specifically cleaning, or sealing with paint or polyurethane, that point of failure. There was no practical applicability or statistical usefulness of further wipe testing at this stage, and therefore, further tests were not taken (with the exception of the 11 units noted above) and are not included in the statistical findings above. All units were ultimately cleared and determined to have effectively passed the NIBS Guidelines for clearance.

C. Field Analysis of Different Abatement Methods

The research design of the demonstration called for extensive testing of six different methods of lead-based paint abatement: encapsulation, enclosure, chemical removal, abrasive removal, hand-scraping with a heat gun, and replacement. Each of these abatement methods was to be tested on the full range of substrates for which it was deemed to be feasible. This design was implemented in the field with one major exception. Abrasive removal abatement methods proved to be infeasible in almost every instance that they were attempted. As a result, following the rules of the Abrasive Unit Abatement Strategy, the second choice, the chemical removal abatement method, was substituted for abrasive removal abatement methods for almost all the substrates scheduled for abrasive removal.

The field experience of lead-based paint abatement in the demonstration was carefully documented through the maintenance of daily logbooks on the problems and progress of abatement in each unit. That information supports a number of general conclusions on the advantages and disadvantages of different abatement methods.

The following is a summary of the practical utility of lead-based paint abatement methods based on the findings of the Contractor's field coordinators. Where necessary, a methodology has been broken down for discussion purposes into more than one process (for example, replacement is discussed as both off-site chemical removal and as removal/replacement).
Each of the methods that follow was also defined as a generic abatement specification in the contract documents.

1. Encapsulation

The encapsulation abatement specification is a "quick cure" that is easy to apply and that immediately improves the aesthetic value of the substrate and dwelling unit. However, care must to be taken that adequate surface preparation work, such as the removal of chipping, flaking paint prior to coating, and preparation of the adhesion surface be undertaken. The encapsulation abatement method cannot be used on friction surfaces such as window tracks and door jambs where the encapsulation surface is subject to failure. It must also be noted that the lead hazard is only covered by encapsulation; the lead is not removed.

It is critical that a long-term study regarding the durability and effectiveness of encapsulation be undertaken.

2. Encapsulation with Flexible Wall Covering Systems

Flexible wall covering systems of a reinforced fiber type that formed a secure bond with the substrate to be abated were used on a limited basis during the demonstration. This system generally worked well on flat wall surfaces but required proper surface preparation. This method is quickly applied and durability at installation is very good, but it should be monitored for long-term effectiveness.

3. Abrasive Removal

Abrasive removal by sanding (with a HEPA) was attempted on numerous occasions during the demonstration with little success. This specification requires that the substrate surface be flat and have an area large enough for the abrasive surface of the mechanical sanding device (pad, disk, etc.) to fit flush against the substrate. At best, this would be the flat surface of a door or wide trim. One problem with this, however, is that on most doors or window trim, a large flat area is often accompanied by smaller, hard-to-reach areas. Additionally, the abrasive material on the sanding pad or belt quickly becomes clogged with paint, therefore requiring a large number of changes of the grit pad; this is costly in both time and materials. Also, use of this abatement method was limited from the outset because most of the substrates identified as having lead-based paint were not flat, (e.g., chair rail, window trim, crown molding, etc.) or could not endure abrasive action (e.g., dry wall). This method also generates a large amount of potentially hazardous dust and is a very slow process, even under ideal conditions. HEPA attachments to collect dust generated were found to be ineffective in most instances.

4. Vacuum Blasting

Blasting used during the demonstration was of the full-containment vacuum type designed to be in full compliance with American Society of Mechanical Engineers, OSHA, and all codes that govern the removal and handling of hazardous materials. The various blasting media tested were non-toxic and conformed to the recommendations and specifications of the vacuum blasting machine manufacturer. The abrasive (vacuum blasting) abatement specification was attempted several times during the demonstration; the results were generally poor, but depended heavily upon the nature and condition of the substrate. Great care must be taken to protect the substrate from damage during the blasting process by adjusting the force used to blast the medium. Experience showed that this method was very costly for the abatement of small surface area substrates due to the fixed capital/rental costs of the required equipment. It should also be noted that this abatement method has the potential to produce a greater amount of waste, by weight, than other abatement methods because the blast medium is included with the lead-based paint removed. The application of this specification is limited to sound masonry substrates, a very limited number of which were available during the demonstration.

5. Hand-Scraping with Heat Gun

The use of the heat gun for abatement produced mixed results, working very well in some instances, but not as well in others. The use of a heat gun is very labor-intensive, requiring a considerable amount of time for removal of lead-based paint from large surface areas. It can generate high levels of airborne dust lead, which in turn creates a greater risk hazard to the abatement worker and makes the final cleanup process more difficult. Similar to the abrasive removal technique, the heat gun is hard to use on detailed substrates that are not flat (but is probably more effective than abrasive removal). The heat gun worked better on wood than metal and masonry substrates. The effectiveness of the heat gun is largely dependent upon the experience of the user and the type of substrate.

6. Chemical Removal

Chemical removal can be one of the most effective means of removing lead-based paint from a variety of substrate types, and it removes the lead hazard permanently. Labor intensity depends on the level of experience the abatement worker has in using chemical strippers, the amount and the type of stripper used, the weather and temperature, the substrate, and coating characteristics. All of these factors determine whether or not more than one iteration of the stripping process is required. In addition, all substrates that are chemically stripped must be thoroughly washed down and neutralized before a priming or sealing coat can be applied. Care must be taken to ensure that the chemical stripper is not left to react on the substrate too long, as this may cause the grain of the wood to rise and become fuzzy in appearance. The chemical stripping compounds used throughout the demonstration required, on average, 24 hours or more to react. The time allowed for reaction and removal is critical; if the stripper compound is not on long enough, a second iteration is necessary. If left on too long, the stripping compound dries out and becomes very difficult to remove.

During the chemical compound removal process, a great amount of chemical and lead-based paint waste was generated. This waste was treated as hazardous due to the high pH values and the amount of lead particles contained in the waste. This method requires that a great deal of precautionary measures be taken to protect the abatement worker, including protective clothing, eye protection, and respiratory protection; and to protect the surroundings. Care must be taken when chemically stripping trim (e.g., window, door, baseboard, etc.) that walls and floors are adequately protected. Experience shows that chemical stripping does not work well on plaster or gypsum board substrates because these substrates absorb moisture and deteriorate during the removal process. Overall, the chemical removal abatement specification is generally effective in abating lead hazards on a range of surface types and does not require a high level of worker skills. Chemical removal is, however, quite time-consuming, requires stringent worker protection, generates considerable hazardous waste, and does not work at low temperatures.

7. Enclosure with Paneling

Enclosure with paneling was tested as part of the demonstration, using prefinished plywood paneling at least 5/32 inch thick of good (1) grade, lauan backing veneer with type II bonding glue. The paneling was attached with nails or screws and an adhesive for bonding paneling to framing or existing surfaces. The adhesive was used to prevent a billowing effect that could cause dust lead to be forced out from behind the paneling, particularly on uneven substrates. This abatement method was used by several abatement contractors as an alternative to using gypsum board, which is more costly, as an enclosure. The method is cost-effective, can be used during inclement weather, and does not require a great level of skill to apply. However, because it does not remove the lead, care must be taken to prevent the removal of the paneling in the future.

8. Enclosure with Gypsum Board

Gypsum board in accordance with ASTM C36-70 or Federal Specification SS-L-30C, Type II, Grade R, Class I, 1/2 inch thick was used as an enclosure for the demonstration. This abatement method was proven effective in abating the lead hazard, but does not remove the lead for future exposure. As with paneling, care must be taken to prevent the removal of the gypsum board in the future. Both screws and adhesives were used to ensure that a secure, long-lasting enclosure was obtained. This process required that the abatement workers be skilled in dry wall finish work. This method is used only on walls and ceilings and may require that additional trim be added to baseboard, window, and door trim, as well as the extension of electrical sockets.

9. Exterior Enclosure

Fabricated enclosure systems of aluminum, vinyl, and wood were used in the demonstration with favorable results. Generally, there are a number of products readily available for use as exterior enclosure; however, some additional surface preparation must be undertaken to prevent deteriorated paint surfaces from being released from the edges of the enclosure systems. This was accomplished by applying a dust-restrictive fibrous membrane to the exterior prior to the installation of the enclosure system. Enclosures were installed in the same manner as conventional siding. One negative aspect of enclosure is that the lead hazard is abated, but the lead is not removed; therefore, the potential for future lead exposure exists.

10. Off-Site Chemical Removal

This abatement specification was designed to provide the abatement contractors with an alternative to intricate on-site chemical removal. However, this alternative was not selected by most abatement contractors during the demonstration. Chemical removers that were harmful to the substrates or those containing methylene chloride were not permitted. One major advantage to the off-site stripping process is that the abatement contractor does not have to worry about the disposal of the hazardous waste that is generated; this responsibility is assumed by the off-site chemical stripping contractor.

11. Removal and Replacement

All substrates that were removed were replaced with a material of the same or better quality. This included substrates such as door systems, window systems, base moldings, chair rails, crown moldings, and porch systems, etc. There are a number of advantages to the removal and replacement abatement specification. By removing lead-based paint containing substrates, the lead is removed from the unit permanently. Often substrates such as window and door systems that are damaged or deteriorated are replaced with new, functional systems, and the result is an overall better living environment. There are several disadvantages to the removal and replacement abatement specification. Costs for replacement of door and window systems can be high. Trained abatement workers must possess a variety of skills, including carpentry, to properly carry out this abatement specification. The material that was removed on the demonstration was considered construction waste; however, should regulations and testing procedures become more strict, this material could require treatment as hazardous waste. Overall, this method proved to be one of the best long-term and most versatile abatement methods.

D. Other Factors Influencing the Efficacy of Abatement

In addition to the specific findings summarized above, several important general factors found during the demonstration to impact the efficacy of abatement methods are presented below:

1. Contractor Background

Twelve different contractors participated in the demonstration. Of these, 10 were active in the asbestos abatement industry and two were general construction contractors. Asbestos abatement contractors frequently recruited local labor from the construction industry to work on the demonstration.

The drawback to using contractors from the asbestos abatement industry was their lack of expertise in construction practices, (e.g., carpentry, plumbing, and electrical work). The asbestos abatement contractors did, however, have a good working knowledge of the required safety and worker protection specifications.

On the other hand, the main drawback to general construction contractors was their lack of knowledge regarding worker safety and protection protocols, which were strictly adhered to throughout the project, and the importance of final cleaning. Experience shows that it is easier to educate construction contractors in the practices of safety and worker protection than it is to educate asbestos abatement contractors in the practices of construction; in fact, on several occasions, asbestos abatement contractors subcontracted the construction work.

An issue facing both types of abatement contractors was their lack of experience in previous lead-based paint abatement work. In fact, only two of the abatement contractors performing the work had any previous experience abating lead-based paint prior to this demonstration. The result was a learning process that lasted several weeks and caused low abatement efficiency during the start-up period.

A direct factor in the efficacy of the cleanup process was the attention of the abatement contractor to several factors, including adequate sealing of surfaces with polyethylene sheeting prior to abatement, proper daily cleanup practices, and attention to detail. It became apparent early in the demonstration that, when a unit was properly sealed with polyethylene sheeting over the floors and cabinets, the final cleanup process moved much faster and easier, especially when coupled with a regimented daily cleanup program. In instances where poor worksite preparation was employed, additional cleaning was often required to meet the clearance levels outlined in the NIBS Guidelines.

Motivation and dedication also played an important role in the effectiveness of the cleanup effort. Field observations showed that the success of some abatement contractors in passing clearance dust lead wipes on the first round was largely dependent on the thorough cleaning of the units by conscientious work crews. The reverse was also noted; less motivated abatement contractors experienced an increased number of failed clearances.

2. Condition of the Dwelling Units

The physical condition of the dwelling units prior to abatement frequently left much to be desired. On numerous occasions, floors were cleaned by abatement contractors, only to be littered with falling plaster from deteriorated ceilings the following day. The cleaning and sealing of deteriorated hardwood and vinyl flooring was also very difficult -- a situation that abatement contractors encountered almost daily. The lack of electricity and running water on-site also presented problems for abatement contractors trying to provide quality work under adverse working conditions.

3. Climate

The role that climate played on the efficacy of lead-based paint removal was significant. Problems were encountered in all cities due to weather, particularly cold temperatures during the period from December 1989 - February 1990. Most of the units to be abated did not have electricity and/or functioning heating systems. Initially, abatement contractors heated these dwelling units with portable propane heating systems, a practice that was abandoned as the result of NIOSH concerns regarding the safety of these heaters. This resulted in delays in the abatement process, particularly in Denver, Baltimore, Washington and Indianapolis.

4. Product Selection

Efficacy of lead-based paint removal was also largely dependent upon the different products that were used throughout the demonstration. Abatement contractors bidding the project were furnished with a list of approved products from which they could choose. They were also permitted to submit additional products for approval by providing an adequate description of the product and Material Safety Data Sheet (MSDS) to the Contractor. If the product met all of the worker protection and safety requirements of the contract documents, and was certified by the manufacturer that it met an abatement specification of the contract documents, the material was approved for use by the abatement contractor. Many abatement contractors tried several different types of chemical strippers and encapsulants. Experience showed that the manufacturers' claims sometimes could not be substantiated under field conditions.

VII. WASTE DISPOSAL

A. Hazardous Waste Determination

Waste disposal was one of the major challenges of the demonstration. In an attempt to meet this challenge and responsibly dispose of the waste generated in the demonstration, the Contractor expended considerable effort to determine the level of hazardous conditions, establish State disposal requirements, and actually dispose of the waste.

The first step in the disposal of waste was to develop a comprehensive protocol for the collection of waste material samples generated throughout the abatement sites of the demonstration. The second step was to analyze these samples in order to arrive at a hazardous or non-hazardous determination as defined by RCRA. Under RCRA, a waste may be considered hazardous either because of its characteristics or because it is specifically listed as hazardous. The four characteristics are ignitability, corrosivity, reactivity, and toxicity. A brief description of each of these characteristics as defined in the Code of Federal Regulations, Part 40 is provided below:

Ignitability (40 CFR 261.21) - to identify wastes that are easily combustible or flammable under routine storage, disposal and transportation or are capable of severely exacerbating a fire once started.

Corrosivity (40 CFR 261.22) - to identify wastes that might pose a hazard to human health or the environment due to their ability to mobilize toxic metals if discharged into a landfill; corrode handling, storage, transportation, and management equipment; or destroy human or animal tissue in the event of inadvertent contact.

Reactivity (40 CFR 261.23) - to identify wastes that, because of their extreme instability and tendency to react violently or explode, pose a problem at all stages of the waste management process.

Extraction Procedure (EP) Toxicity (40 CFR 261.24) - designed to simulate the leaching a waste will undergo if disposed of in a sanitary landfill. If the extract obtained from the method contains any of the regulated substances (in this case, metals) in an amount equal to or exceeding specified levels, the waste possesses the characteristic of Extraction Procedure Toxicity and is a hazardous waste.

Samples were collected by the Contractor's field coordinators in four of the five metropolitan areas using the protocols established by the Contractor in coordination with the EPA. Because sampling and analysis of the waste was conducted prior to the commencement of abatement activities in the Seattle/Tacoma area, officials from the State of Washington reviewed and adopted the test results reported from the other four research groupings. Each sample was collected and stored in 100-gram sample bottles provided by the Contractor's laboratory and was labeled with the unit address, sample number, the date the sample was taken, and specific contents of the sample. The results of this sampling had a far-reaching impact on the future conduct of the demonstration with respect to hazardous and non-hazardous waste management. The following paragraphs describe the process used for sampling of waste generated by each specific Unit Abatement Strategy.

Two units with Removal and Replacement as the primary Unit Abatement Strategy were selected for sampling at each research site. A representative portion of each substrate removed during abatement (at least 200 grams each) was collected to form a composite sample on a per-unit basis. For example, in units where window and door systems were removed and replaced, representative samples of window sills, window trim, window sashes, door frames, doors, and cleanup debris were taken to form the composite sample.

The Chemical Removal Strategy required more samples than the Remove/Replace Strategy because of concerns regarding toxicity of the chemicals, as well as the paint residue. For each different chemical stripping compound that was used in the demonstration, two units were sampled, until it was determined that this Unit Abatement Strategy always generated hazardous waste. Samples that were taken for units where Chemical Stripping was the primary Strategy included quantities of chemical sludge containing lead-based paint; and composite samples of protective body suits, respirator filters, rags, mops and polyethylene sheeting. A sample of dust and the filter from a HEPA vacuum were also taken. Liquid samples of the wash water resulting from the wash-down of chemically stripped substrates were taken; these samples included neutralizer and TSP rinse water. Filtered (five micron) rinse water was taken, as was a sample of the five micron filter and resulting residue. When the HEPA vacuum was used to accumulate rinse water, samples of that water were also taken.

Two Abrasive Removal Strategy units were sampled for material that was sensitive to the high level of dust that was created by this Strategy. Samples were collected from HEPA vacuum filters and respirator filters. A similar approach to the Hand-Scraping with Heat Gun Strategy resulted in the collection of samples inherent in the heat gun process, specifically, hand-scraped paint residue. In order to provide a comprehensive profile that was sensitive to field conditions in each metropolitan area, field coordinators were also given the opportunity to sample any debris that they felt did not fall into one of the categories described above. Any debris generated from the Encapsulation or Enclosure Unit Abatement Strategies was considered equivalent to samples taken from the other strategies, and was therefore not independently sampled.

A total of 76 samples were collected and analyzed for one or more of the four hazardous characteristics. All 76 samples were analyzed for lead content under the toxicity characteristic by the Extraction Procedure (EP) toxicity test. Twenty of the 76 samples were analyzed for all characteristics where feasible. Prior to analysis, the samples were placed into one of the eleven categories listed below:

1. Paint chips from chemical stripping, heat gun removal, abrasive removal, or surface preparation for encapsulating or enclosing
2. HEPA debris, dust from air filters, paint dust
3. Woodwork, plaster, window and door systems, and any other substrates removed for replacement
4. Polyethylene sheeting used to protect floors and other surfaces
5. Solvents and caustics used during chemical stripping
6. Sludge from chemical stripping
7. Rinse water
8. Rags, mops, sponges, HEPA filters, air monitoring cartridges, scrapers, and other materials used for testing, abatement, and cleanup
9. Disposable work clothes and respirator filters
10. Rugs and carpets
11. Blanks

Based on laboratory analysis, the following materials were identified as hazardous and were systematically separated during the abatement process from non-hazardous waste for disposal purposes.

- paint debris from chemical stripping, heat gun removal, abrasive removal, or surface preparation for encapsulating or enclosing

- non-filtered waste water, rags or towels used to aid in the cleanup of chemical stripper residue
- HEPA vacuum bag debris
- HEPA vacuum filters
- any other material, particularly polyethylene sheeting, that became grossly contaminated with any of the aforementioned materials during the abatement process

A complete listing of the hazardous waste characteristic results can be found in Appendix L.

B. Hazardous and Non-Hazardous Waste Disposal

The characteristic test results were presented to appropriate State officials in each of the metropolitan areas. State agency response showed considerable variations in direction for disposal. These variations directly impacted the disposal process, as the Contractor was required to tailor the disposal management plan on a state-by-state basis. Enumerated below are state-specific descriptions of the various waste disposal management plans.

Colorado (Denver) - The Colorado Department of Health required that any waste that was tested and labeled hazardous be separated from non-hazardous construction waste and be disposed of through the hazardous waste manifest system. Hazardous waste disposal was contracted through a local hazardous waste disposal firm that packaged, transported and delivered the waste to an out-of-state, EPA-certified hazardous waste landfill. Non-hazardous construction waste was permitted to be taken to a sanitary landfill for disposal.

Alabama (Birmingham) - Initially, the Contractor was instructed by the Alabama Department of Environmental Management (ADEM) that all waste generated on the demonstration could be disposed of in a lined landfill. As time passed, ADEM officials took a more conservative stance and directed the Contractor to dispose of hazardous waste through the hazardous waste manifest system. Hazardous waste disposal, therefore, was contracted through a national firm that collected, transported, and delivered the waste to an EPA-certified hazardous waste landfill where it was shredded prior to final disposal. Non-hazardous construction waste was taken to a sanitary landfill for disposal.

Indiana (Indianapolis) - Officials with the State of Indiana requested that all waste be disposed of in a licensed solid waste disposal facility based on the EPA "conditionally exempt small generator" status. In addition, the Contractor packaged the waste in 6-mil bags inside cardboard boxes prior to disposal. A hazardous waste manifest system was not required.

Maryland (Baltimore) - The Maryland Department of the Environment (MDE) required that disposal of waste generated in the course of the abatement process be in compliance with hazardous waste small quantity generator and household exemption regulations as required by COMAR 10.51.03. The waste was therefore disposed of in a lined landfill.

Washington (Seattle/Tacoma) - Legislation recently passed in this state led to the disposal of all hazardous waste through the hazardous waste manifest system. Officials did permit the abatement contractors to accumulate hazardous waste in one site per abatement contractor, thereby reducing the cost of collection from 26 individual sites to only three sites. Non-hazardous waste was taken to a sanitary landfill for disposal.

Washington, D.C. - Due to a lack of direction from officials in the District of Columbia, waste generated in the three dwelling units located inside the District limits was disposed of in compliance with regulations in the neighboring State of Maryland.

As stated above, waste that was generated in Denver, Seattle, Tacoma and Birmingham, which was disposed of as hazardous waste, was collected, transported, and delivered to the appropriate hazardous waste disposal facilities by a licensed hazardous waste handler. Prior to the collection of waste, the hazardous waste handlers conducted independent waste stream analyses to characterize the materials to be disposed. These waste stream analyses were a compilation of representative quantities of the heterogenous hazardous material in order to:

1) verify the contents as characterized by the Contractor
2) determine the overall lead content and pH of the materials
3) confirm that additional processing of waste was not required prior to disposal

C. The Cost of Waste Disposal

It is not within the scope of the demonstration research design to speculate on whether waste generated by the abatement of residential lead hazards will or will not be permitted to qualify for the domestic exception from RCRA. Accordingly, the discussion of hazardous waste disposal costs presented here will be confined to an analysis of the cost experience in Denver, Birmingham, and Seattle, those cities in which hazardous waste disposal was required.

The costs of the waste stream analysis, pick-up and disposal were $9,625 in Denver, $4,657 in Seattle, and $10,221 in Birmingham. The waste generated in Baltimore/Washington, D.C. and Indianapolis was not treated as hazardous waste, as indicated above, and was disposed of in local landfill sites.

Estimates of the number of pounds of hazardous waste per dwelling unit abated were developed by counting the number of bags/barrels of hazardous materials at each dwelling unit and tabulating the total weight of disposed hazardous waste at each research site. On average, 216.7 lb. of hazardous materials were generated per dwelling unit across all three research groupings (128.9 lb. in Denver, 517.4 lb. in Birmingham and 96.9 lb. in Seattle/Tacoma). The average cost of disposal across all three research groupings was $1.18 per lb. ($1.31 in Denver, $0.86 in Birmingham and $3.02 in Seattle/Tacoma) or $255.43 per dwelling unit ($168.86 in Denver, $444.39 in Birmingham and $292.19 in Seattle/Tacoma).

The cost of hazardous material disposal was strongly influenced by the Unit Abatement Strategy to which the dwelling unit was assigned. The average volume and cost of hazardous waste disposal per dwelling unit by Unit Abatement Strategy is presented in Table VII-1.

Table VII-1

AVERAGE VOLUME AND COST OF HAZARDOUS WASTE DISPOSAL BY UNIT ABATEMENT STRATEGY

Unit Abatement Strategy	Average Volume (per house) of Hazardous Materials (lb.)	Average Cost (per house) of Hazardous Waste Disposal
Encapsulation	99.2	$117.02
Enclosure	104.5	$123.36
Chemical	436.0	$514.48
Hand-Scraping w/Heat Gun	260.5	$307.42
Replacement	117.5	$138.65

A further examination of the effects of Unit Abatement Strategy on the amount of hazardous waste generated was performed using regression analysis in the same way that the influence of abatement method on indirect labor and materials costs was examined. The estimated regression was:

$$\text{Pounds of Hazardous Waste Generated} = \underset{(0.09)}{0.04 \cdot \text{SFREPL}} + \underset{(0.03)}{0.10 \cdot \text{SFENCAP}} + \underset{(0.14)}{0.11 \cdot \text{SFHS}} + \underset{(0.12)}{0.85 \cdot \text{SFCHEM}} + \underset{(0.05)}{0.02 \cdot \text{SFENC}}$$

$R^2 = 0.45$ $F = 15.5$ Standard Errors in Parentheses

where SFREPL denotes square feet abated using the replacement method, SFENCAP denotes square feet abated using the encapsulation method, and so on.

This further confirms the extremely high costs of hazardous waste disposal when chemical methods are used. Based on the limited demonstration experience, a further $0.99 (0.85 lb. x $1.18 /lb.) per square foot would be added to the costs of abatement by on-site chemical stripping.

D. Waste Processing Observations for Lead-Based Paint Abatement

In summary, although waste disposal was one of the major challenges of the demonstration, the result was a ground-breaking opportunity to collect and analyze waste generated during the abatement of lead-based paint on a national level. Significant observations were made with respect to the waste generated on a lead-based paint abatement project in single-family dwellings. These observations are summarized below.

- Certain abatement waste products (previously listed in this chapter) can and should be anticipated in any abatement program.

- Care must be taken to limit and/or control the amount of hazardous waste generated. Daily cleanup and proper storage of materials used on the project enable the abatement contractor to keep a clean, well-organized site, and in turn keep the contamination of surrounding work areas at a minimum, thereby reducing the amount of hazardous waste generated. Collecting and storing the hazardous wastes separately from other waste is essential.

- Abatement contractors must be certain before abatement activity begins that a preliminary waste disposal management plan is proposed to local, State and Federal agencies representing that area. Upon commencement of abatement activity, it is important to take samples of the waste as early as possible and have them analyzed so that appropriate officials can finalize the plan. Written confirmation of all authorizations and instructions should be required.

- Where abatement contractors are directed to dispose of waste in a sanitary landfill or through a hazardous waste manifest system, the RCRA guidelines must be followed to insure proper record-keeping.

- Waste disposal must be considered an integral part of any lead-based paint abatement contract.

VIII. ABATEMENT CONTRACTING: PROCESS AND PERFORMANCE

The abatement contracting process involved the development of a series of documents that would provide for the encouragement, open competition, and sound contracting of the abatement program. The documents were developed with two major objectives in mind.

Objective 1: To develop a comprehensive set of documents that would be in compliance with the NIBS Guidelines for abatement, cleanup, and disposal of lead-based paint.

Objective 2: To provide a set of documents that would insure that abatement contractors perform the prescribed abatement methods consistent with the objectives of the research design.

The following sections will illustrate efforts of the Contractor to accomplish these objectives and will elaborate on additional factors of the abatement contracting process including product utilization, development of bid quantities, and abatement contractor selection.

A. Contract Document Development

The contract document development drew heavily on both the Contractor's experience in architectural services for the public and private housing industry and knowledge of the NIBS Guidelines for abatement, cleanup, and disposal of lead-based paint. The NIBS Guidelines were regarded as the most complete and up-to-date source of information on lead-based paint with respect to testing, abatement, cleanup and disposal, and the document on which future lead-based paint abatement related activities will be modeled. The contract document development also considered the importance of creating a document whereby abatement contractors would carry out the appropriate abatement methods detailed in the research design, a critical factor to the successful collection and analysis of abatement time and motion observations. This was accomplished by utilizing generic abatement specifications for the abatement methods identified in the research design and by developing a detailed plan for the collection of time and motion data on a per-dwelling unit basis. The generic abatement specifications for each of the abatement methods, found in the contract documents, and data collection forms are included in Appendices A and E, respectively.

An abatement contract document summary is included as Exhibit VIII-1 at the end of this chapter.

The entire package of contract documents and Instruction to Bidders is included in Appendix A of this report. Their utilization is encouraged where appropriate; however, users are cautioned that the passing of time will date some of the material, especially applicable Federal Regulations.

1. Abatement Specifications

For contracting purposes, a set of generic (i.e., specifying no particular brand of product) abatement specifications was developed. This set of specifications, A-K, is listed below with the corresponding abatement method to which the specifications were attributed.

Specification	Abatement Method
A - Encapsulation	Encapsulation
B - Abrasive Removal	Abrasive Removal
C - Heat Gun Removal	Heat Gun Removal
D - On-Site Chemical Removal	Chemical Removal
E - Vacuum Blasting	Abrasive Removal
F - Enclosure with Paneling	Enclosure
G - Enclosure with Gypsum Board	Enclosure
G-1 - Exterior Enclosure	Enclosure
H - Off-Site Chemical Removal	Enclosure
I - Remove/Replace	Remove/Replace
J - Flexible Wall Coverings	Encapsulation
K - Submittal by Engineer	As Appropriate

2. Bid Quantities

The development of bid quantities was undertaken by the Contractor, as opposed to the abatement contractor. The reasons for this were threefold.

First, in advance of the actual bidding process, it was necessary for the specific substrates and the approximate quantities to be identified in order for assignment of Unit Abatement Strategies in accordance with the research design. Second, it was anticipated that a better definition and a concise specification of the work required by the abatement contractors in an area of relatively new procedures would encourage more participation in the bidding process. Third, it was felt that if the quantities were provided by the Contractor, a minimum amount of contingency pricing would be included by the abatement contractors in their bids. In hindsight, provision of the bid quantities by the Contractor was beneficial. In addition to accomplishing the objectives stated above, it also expedited the bidding process.

The quantities were established by the Contractor during the final stages of the testing phase of the demonstration. Specifically, during the AAS sampling program, all quantities for abatement were determined by the measurement of all substrates determined to require abatement as a result of the XRF testing and all substrates that were being tested by AAS.

The bid quantities were presented to the prospective abatement contractors in Part C of the Bid Documents. The Part C's, included as part of the contract, identified on a room-by-room basis the substrates, their quantities, and their assigned generic abatement specifications. The utilization of this bid quantity identification process should be considered for future abatement efforts, especially during the developmental stages of the lead-based paint abatement contracting industry over the next few years.

3. Product Utilization

One objective of the abatement process was to create a real-world environment for the selection and utilization of abatement products. Unfortunately, even at the time of this writing, there are very few standards for the evaluation of such products. The process used for the solicitation of products to be used in the demonstration is described below. Contractor judgment was applied during the selection process in order to approve products to be used in the abatement process.

In anticipation of the demonstration in June of 1988, HUD published an advertisement requesting that any product information or technology pertaining to the abatement of lead-based paint be submitted for review. Respondents to the advertisement were included on a list that was submitted to the Contractor for further action. Subsequently, during the early stages of the demonstration, the Contractor continued the solicitation of abatement products.

After the development of the generic abatement specifications, each submitting manufacturer was requested via letter to confirm in writing that its product met the requirements of one of the generic abatement specifications A through K of the contract documents and to submit a Material Safety Data Sheet on the product for approval. Upon approval by the Contractor and NIOSH, the product was included on a list of approved products, which included the product trade name and type of product, and the manufacturer's name, address, and telephone number (Appendix M). This list was distributed to all potential abatement contractors for use in the preparation of bids. The product manufacturers were also given a list of eligible abatement contractors, to which they could market their products.

Ultimately, the utilization of some products was determined by the success of the abatement contractors in using those products. At no point has the abatement contractor been held responsible for the durability of the products, nor was the durability of the products a subject of the demonstration; however, abatement contractors were expected to follow product manufacturers' instructions regarding application/usage.

B. Abatement Contractor Selection

The abatement contractor solicitation and selection process, initiated during the early phases of the demonstration, was developed to secure quality abatement contractors that could meet the requirements of the Contractor, and to promote equitable distribution of the available work. Extensive efforts, as described herein, were taken by the Contractor to find and encourage potential bidders. The ultimate selection criteria for qualified firms was based on cost. The net result of the process was that the Contractor was able to find a sufficient number of abatement contractors to consider the bidding process successful. However, the work, quality, and timeliness of the abatement contractors varied from good to very poor.

1. Initial Investigation During Advance City Team (ACT)

The ACT initiative, conducted in the early phases of the demonstration, was employed in part to be the first search for potential abatement contractors at each research site. During this phase, Contractor staff researched the local labor and construction markets to determine available abatement contractors and minority abatement contractors, and to identify local codes and permit procedures in each of the cities of the demonstration.

2. Solicitation Process

Potential abatement contractors were identified through the use of business telephone directories and through advertisements placed in the newspapers of each of the cities. In addition, HUD and local Fair Housing and Equal Opportunity Offices were contacted to secure a listing of minority firms, Disadvantaged Business Concerns (DBC), Women-Owned Business Concerns (WOBC) and small business firms that could be considered potential abatement contractors.

The potential abatement contractors were then solicited by telephone and mail to inform them that the Contractor would be conducting initial site visits in each of their cities.

3. Contractor Meetings (Site Visits)

The initial site visits consisted of a series of meetings at each of the research sites for the purpose of informing the local contracting industry about the demonstration, its objectives, the need for abatement contractors, and their role. It was intended as an effort to encourage local contractors to become interested and to bid on the abatement work. The Contractor presented the potential abatement contractors with a description of the Scope of Work and other contract documents, and requested that interested abatement contractors complete and return a pre-qualification application. Several weeks after the initial site visit, abatement contractors that returned pre-qualification applications were eligible to attend an on-site pre-bid conference meeting. This meeting assembled groups of five to ten potential abatement contractors that were given a set of draft contract documents and were taken to several of the dwelling units scheduled to undergo abatement. The main objective of the meetings was to familiarize the abatement contractors with the contract documents and to answer questions from the abatement contractors. At these meetings, each section of the contract documents was explained in detail, particularly Part C, which is the itemized listing of substrates, quantities, and corresponding generic abatement specifications.

Abatement contractors were informed that the units at each research site would be divided into groups of about five units each and were encouraged to bid on all of the groups to improve their chances of receiving work.

Potential abatement contractors were given one week to familiarize themselves with the bid documents before a set of final contract documents (including the Instruction to Bidders) was distributed. Abatement contractors were then given approximately three weeks to prepare their bids. Sealed bids were accepted until 5:00 p.m. on the specified date, then opened and reviewed by the Contractor for completeness, accuracy, and cost on a line-by-line, part-by-part basis. In addition, the prospective abatement contractors' client references were verified and their product submittals were reviewed before negotiations were initiated. Following successful negotiations, contracts were prepared.

Several factors were encountered during the abatement contractor solicitation process that made the process difficult. The majority of the abatement contractors that responded to the advertisements were from either the asbestos abatement industry or home improvement/renovation industry. The Contractor found that neither was truly qualified to perform lead-based paint abatement work. Asbestos abatement contractors were well-versed in the worker protection and safety aspect of the job, but did not have the expertise required to perform quality, efficient, remodeling-type work. On the other hand, the general contractors or remodeling-type contractors had no problems with the remodeling work, but had difficulty adjusting to the worker protection and safety aspects of the job. Another consideration was the fact that most contractors had little or no experience with particular methods of the work and had little or no concept of how to bid items like paint removal with a heat gun or chemical stripper. This apprehension resulted in a wide range in the dollar amount of the bids; therefore, a great deal of time was spent comparing and negotiating bids.

Some abatement contractors were apprehensive about working on a research project that was funded by the Federal Government. The Contractor went to great lengths to counter this concern. Perhaps the most significant action by the Contractor was to commit to paying abatement contractors on a bi-weekly basis.

4. Final Abatement Contractor Selection

Only firms deemed qualified as a result of a review of the qualification questionnaire were given the chance to bid the abatement work. Upon receipt and review of the bids, the qualified bidder considered lowest in cost was selected. Negotiations were held with the lowest bidder and these were usually successful in reducing costs by clarifying and settling concerns held by the abatement contractor. Finally, a contract was prepared and executed. Table VIII-1 summarizes the results of the solicitation and bidding process by research site.

C. Abatement Contracting Performance

The most vital characteristic of a successful abatement contractor is his/her ability to manage and supervise construction/abatement efforts effectively. While abatement contractors from various contracting backgrounds participated in the demonstration, it was those who possessed this ability that exhibited superior performance. With that in mind, the following sections of this chapter will describe abatement contracting performance with respect to scheduling, mobilization, and set-up. Chapter VIII reports on abatement contractor performance for the different methods of abatement that were tested in the demonstration and the success and failure of dwelling units in meeting final clearance standards. Discussions of field coordination are also included, as they had a direct impact on abatement contractor performance.

TABLE VIII-1
ABATEMENT CONTRACTOR SUMMARY

Research Site

	Denver	Birmingham	Indianapolis	Baltimore/ Washington, D.C.	Seattle/ Tacoma	Total
Number of Contractors Solicited for Demonstration	37	24	41	22	33	157
Number of Contractors Bidding	7	4	5	4	5	25
Number Contracted	4	3	3	3	3	16

1. Scheduling/Mobilization

Abatement contractor performance began with a successful scheduling and mobilization effort. This effort set the stage for future performance.

Prior to the initiation of the actual mobilization process, abatement contractor personnel participating on the demonstration were required to undergo a physical examination that was sensitive to potential previous exposure to lead. The examination was also required to include a certification that employees could wear protective respiratory equipment, and a blood analysis to determine pre-abatement blood lead levels measured in micrograms per deciliter (ug/dl - see Worker Protection, Chapter IV).

All abatement contractor personnel were required to be trained in worker protection and safety. For purposes of uniformity, abatement contractors were certified under the "Maryland State Lead Paint Abatement Health & Safety Training Certification" COMAR 26.02.07.11. The Maryland State Certification was adopted because at the outset of the demonstration, no other states had yet established similar regulations. The cost of the training program was borne by the Contractor; however, abatement contractors were expected to carry the costs of their employee wages for attending the six-hour training program. The Health and Safety Training Manual used during the training can be found in Appendix K.

Upon completion of the required physical examinations and training certifications, each abatement contractor determined his/her own mobilization plan. Several abatement contractors chose to mobilize and set up three to four units at one time, and then initiated the abatement work using teams of four to seven crew members at each unit. Other abatement contractors chose to use crews of five to ten and tried to complete one or two units at a time. The performance of each crew depended on the supervision it received. Both approaches worked for some abatement contractors and not others. It was apparent that a crew of about four to six could work on one unit at a time effectively, provided the abatement contractor field superintendent was well organized, was respected by the crew, and was able to furnish the crew with the materials that were required to get the job done. Too often the field superintendents were not able to effectively manage their crews, particularly when more than one or two units were involved or when more than about five or six abatement workers were employed per unit.

2. Set-up

The objective of a detailed set-up procedure is to prepare the abatement area such that effective abatement activity and an efficient final cleaning can be conducted. Abatement contractors were directed to strictly adhere to the procedures detailed in Section I of the contract documents, entitled, Set-up Procedures for Abatement. A brief description of those procedures is outlined below with respect to abatement contractor performance.

- Abatement contractors were required to post warning signs immediately outside all entrances and exits to the dwelling units three days in advance of any abatement activity.

- No persons were granted entrance to the units unless they had successfully completed the worker protection training provided by the Contractor. Several instances arose in which abatement contractors required an additional training session because of high employee attrition. Additional training was held at the abatement contractor's expense. It should be noted that the policing of the limited access requirement was not 100% effective. Often, persons not associated with the abatement operation ignored the warnings and entered without permission. These people included realtors, property managers, and "street people."

- Protective clothing was required for much of the abatement process, including set-up. Disposable protective whole body suits, head coverings, gloves and foot coverings were specified in the contract documents. While most abatement contractors were willing to comply with these regulations, some abatement contractors persistently pursued short cuts to the use of protective clothing as well as respiratory protection requirements. However, field coordinators continued to enforce the regulations as specified in the contract documents.

- A critical process in the abatement of a unit was the initial cleanup and preparation of the interior work area. All surfaces on dwelling unit interiors were stripped of carpeting, curtains, and any movable furniture including major kitchen appliances and thoroughly cleaned with a HEPA vacuum. It should be noted that carpets were misted prior to removal in order to reduce the amount of dust lead generated. Two layers of 6-mil polyethylene sheeting were then placed on the floor with industrial strength tape and staples. Abatement contractors indicated that the time required to complete this phase of the abatement almost always exceeded their estimates.

- A three-stage decontamination chamber required during the early abatements of the demonstration was constructed with polyethylene sheeting and braced with materials such as wood or polyvinyl chloride piping. The construction of the decontamination chamber was almost always a source of contention between the Contractor and the abatement contractors. A well-built, properly maintained chamber would provide adequate service over an extended period of time. However, the time and effort allotted by the abatement contractor for this task was usually insufficient, resulting in poorly constructed and improperly maintained chambers, an inordinate amount of time for repair and replacement of the chambers and friction with Contractor personnel. During the later phase of the demonstration, in response to NIOSH recommendations, the three-stage decontamination chamber was replaced with a designated clean area.

In summary, conscientious set-up practices are an essential aspect of the abatement process. As the descriptions above indicate, this is an area that should be closely monitored to achieve optimum abatement contractor performance.

3. Field Coordination

The Contractor assigned to each metropolitan area of the demonstration a field coordinator, whose general function was to insure abatement contractor compliance and field data collection, and to assist the abatement contractor during his/her "learning curve" of the processes.

Critical field coordinator responsibilities included:

- visiting each abatement site to answer questions from the abatement contractors
- inspecting the quality of work being performed
- coordinating efforts with the on-site industrial hygienist with respect to air monitoring and final clearance dust wipes
- performing final clearance visual inspections to follow abatement activity
- gathering information from the abatement contractors and disseminating information from the Contractor
- ensuring that waste was being handled properly
- preparing daily field performance reports on each unit
- keeping local HUD property disposition officials apprised of the demonstration status
- escorting regulatory agency officials through units as requested

- ensuring that all substrates identified as containing lead-based paint were abated as assigned in the contract documents, Part C

- reporting and confirming the abatement contractor's requests for payment

In addition to the specific responsibilities listed above, field coordinators often took on additional initiatives as situations arose during the course of the demonstration. This included activities such as answering questions and/or making decisions regarding the continuing effort of a particular abatement method. For instance, when abatement contractors were not getting the productivity they expected under the specified abatement methods, field coordinators directed the abatement contractors to maintain their moderate progress in order to gather enough data to conclusively prove or disprove the efficacy of that particular abatement method. Because of the demanding nature of the liaison role, field coordinators were challenged to perform on-site creative problem-solving in conjunction with the routine daily responsibilities. One significant finding of the demonstration is that until experienced lead-based paint abatement contractors are developed, any program for abatement will go through an extensive and costly learning curve.

4. Industrial Hygiene Monitoring

Industrial hygiene monitoring complemented the field coordinating effort by providing additional support to the abatement contractors. The industrial hygienist was usually responsible for one to three active units. Their efforts specifically included daily inspection of each unit for compliance with worker protection and work place specifications, detailed time and motion data collection, and air and dust lead wipe sample collection (see Appendix N - Quality Assurance Project Plan for Collection of and Analysis of Air and Wipe Samples). As hygienists became familiar with the process, as well as the requirements of the field coordinator, they became effective in assisting the field coordinators in their daily activities.

Exhibit VIII-1

Abatement Contract Document Summary

The abatement contract document is composed of the following:

a) Agreement pages - identified the parties to the contract, the units to be abated, a completion date, the contract sum, a "table of contents" for the contract documents, and a signature page.

b) Bid Documents, incorporated into the contract, including cost breakdowns and quantities - the standardized copy of the bid form is a three-part form that guides the abatement contractor through the required breakdown of his/her bid(s), outlined below, including mobilization (Part A), capital, overhead, cleanup, waste disposal, and set-up (Part B), and itemized listing of the identified substrates to be treated, (Part C).

c) A description of the Abatement Methodology Specifications A-K - assigned in accordance with the protocols of the research design.

d) General Conditions - includes standard contract language typically found in construction-related contract documents; for example, procedures for default, termination, and severability.

e) Performance Bond Document - the American Institute of Architects, (AIA) document A312 (Performance Bond).

f) Payment Bond Document - the AIA document A312 (Payment Bond).

g) Change Order Document - a standard form developed by the Contractor for the purpose of instituting changes to the contract.

h) Notice to Proceed Document - provided as an official written document to formalize the verbal notice to proceed.

i) Notice of Award Document - provided as an official written document to formalize the verbal notice of award.

j) Non-Collusive Affidavit - a form signed by the abatement contractor verifying that his/her bid is independent and free of fraudulent bidding practices.

k) Section I - Set-up Procedures for Abatement - summarized the process to prepare a unit for abatement activity.

l) Section II - Worker Protection - this section, drawing heavily on the NIBS Guidelines, described worker training, biological and air monitoring, and personal protective equipment and practices.

m) Section III - Cleanup Procedures - this section, drawing heavily on the NIBS Guidelines, described the requirements for level of cleanup effort, equipment to be used, standards for cleanup, and final cleanup/inspection procedures.

n) Section IV - Disposal of Waste Materials - described briefly the guidelines for removal of hazardous and non-hazardous waste. This section was ultimately removed from the abatement contracts.

IX. SYNTHESIS OF FINDINGS

In Chapter II, the research objectives of the demonstration were grouped into three major categories:

- Estimating the Comparative Costs of Alternative Lead-Based Paint Abatement Methods
- Assessing the Efficacy of Alternative Lead-Based Paint Abatement Methods
- Confirming the Adequacy of Worker Protection Safeguards used in the demonstration

Previous chapters of the report have presented the separate research findings along each of these dimensions. In this chapter, these findings are reorganized to permit direct comparisons of different abatement methods in terms of their cost, their efficacy and the extent to which they create a need for worker protection. A tabular summary of this information appears at the end of this chapter. These forms of presentation are designed to assist agencies and individuals in selecting the most cost-effective methods of abating lead-based paint hazards in housing.

For the purposes of this discussion, it is useful to distinguish between methods that leave lead-based paint in place but make it inaccessible, and methods that remove lead-based paint from a dwelling unit. The former approach is represented by encapsulation and enclosure methods. The latter approach includes chemical removal, abrasive removal, hand-scraping with a heat gun and replacement of substrates.

A. Cost-Effectiveness of Encapsulation and Enclosure Abatement Methods

The findings of this report on the costs and efficacy of encapsulation and enclosure methods must be interpreted with caution, given the uncertainty about how long these methods will remain effective after installation. The costs reported here are "one-time" costs. If lead-based paint hazards must be periodically re-encapsulated or re-enclosed, the "one-time" costs understate the real costs of containing lead-hazards using these methods.

A more appropriate measure of encapsulation/enclosure costs would then be the initial cost plus the present value of the future stream of costs that would have to be expended to insure that these systems remain effective over time. This measure cannot, however, be constructed until evidence on the durability of encapsulants and enclosure systems becomes available. With these reservations in mind, the findings on the costs and effectiveness of these methods are now reviewed.

1. Encapsulation

Encapsulation is a method of abatement that involves the coating and sealing of surfaces with durable coatings formulated to be elastic, long-lasting, and resistant to cracking, peeling, algae, and fungus. Encapsulants are intended to prevent chalking, flaking lead-containing substances from becoming part of house dust or accessible to children.

Encapsulation was found to be the least expensive of all the methods of lead-based paint abatement for all substrates except doors, where replacement is cost-competitive. Encapsulation typically costs 30% to 50% less than enclosure methods depending on the type of substrate to be abated. Compared to removal methods of abatement, the cost advantages of encapsulation are generally larger and are particularly evident for interior and exterior door frames, shelves, interior and exterior walls, soffits, interior and exterior windows, exterior window sills and window trim. It should be noted that in instances where both interior and exterior surfaces of a window require abatement, the cost for replacement of that window exceeds the cost of encapsulation. However, the durability issue of encapsulation on window systems remains a major factor in specifying encapsulation versus replacement of windows.

In terms of its worker protection requirements, encapsulation was found to be the abatement method that generated the lowest levels of airborne dust lead during abatement. Worker protection requirements were reduced at the suggestion of NIOSH when encapsulation abatement methods were in use and respirators were only used during surface preparation activities.

In terms of various measures of efficacy, encapsulation was found to be quite successful. Encapsulation worked on almost any substrate type given proper surface preparation and was particularly effective on hard-to-reach areas. Units abated using an Encapsulation Unit Abatement Strategy performed well in terms of clearance on wipe tests and generated less hazardous waste than units abated using other strategies.

2. Enclosure

Enclosure is the resurfacing or covering of surfaces, and sealing or caulking with durable materials mechanically affixed so as to prevent or control chalking, flaking lead-containing substances from being part of house dust or accessible to children.

Enclosure is a candidate method for abatement of lead hazards, particularly on large, flat surfaces such as ceilings and walls, although it was also used in the demonstration on window trim, columns and soffits. Because enclosure is uniformly more expensive than encapsulation, it would only be used if encapsulation were eliminated on the grounds of insufficient durability.

Enclosure would be preferred over removal methods for ceilings (where removal methods are generally not feasible), for exterior walls and soffits, and possibly for interior walls, where it costs about the same as hand-scraping with a heat gun.

Enclosure methods appear to generate very little airborne dust lead during abatement and their worker protection requirements are the same as for encapsulation.

Enclosure, although clearly not feasible for many substrate types, may confer aesthetic benefits in some dwelling units and will provide additional thermal insulation when used on exterior surfaces. Dwelling units assigned to the Enclosure Strategy did reasonably well in meeting wipe clearance standards, (although not quite as well as units assigned to the Encapsulation Strategy). Enclosure methods generate relatively little hazardous waste.

B. Cost Effectiveness of Removal Methods

All of the remaining methods tested in the demonstration physically remove the lead-based paint from a dwelling unit.

1. Chemical Removal

Chemical removal is a method of abatement which entails the removal of lead-based paint using chemical paint strippers.

The estimated cost of abatement using chemical strippers is consistently higher than the cost of removing lead-based paint by either hand-scraping or replacement methods. As noted in Chapter V, the differences between the cost of chemical removal and other removal methods are typically quite large, with differences ranging from 44% up to 347% greater, depending upon the type and detail of the substrate. Chemical removal is, however, typically the only feasible removal method for exterior walls, although it is estimated to be seven times more expensive than encapsulation and 3.5 times more expensive than enclosure.

Chemical removal creates more airborne dust lead than encapsulation, enclosure or replacement, but less airborne dust lead than hand-scraping. NIOSH recommended the use of more protective equipment when chemical stripping was used than when other methods of abatement were used.

Chemical removal can be used on a wide variety of substrates, but tends to be dependent on worker skill and is difficult in terms of daily cleanup and containment. Field experience demonstrated that chemical strippers are difficult or impossible to use outside of a moderate range of temperature. Dwelling units that had been assigned to a Chemical Removal Unit Abatement Strategy had the highest failure rates on wipe sample clearance tests and 38% of all units assigned to chemical removal never cleared on the wipe tests prior to priming or sealing. Lastly, the chemical removal methods generated far more hazardous waste than other methods.

2. Hand-Scraping with Heat Gun

The hand-scraping with heat gun method of abatement entails the removal of lead-based paint using a heat gun and hand-scraping tool.

Hand-scraping appears to be less expensive than replacement for windows when only interior or exterior window surfaces require abatement, and about the same cost as replacement for baseboards, window sills, exterior door frames, and when both interior and exterior window surfaces require abatement. It is more expensive than replacement for interior doors and door frames, interior window trim, exterior doors and exterior window trim.

Hand-scraping with a heat gun generates more airborne dust lead than any of the other abatement methods. Respiratory protection is therefore strongly recommended whenever this abatement method is in use.

Hand-scraping is a versatile technique that can be used on a wide variety of substrates, but can be very labor-intensive, particularly when removing lead-based paint from large surface areas or detailed substrates. The heat gun worked better on wood than metal and masonry substrates. The effectiveness of the heat gun is largely dependent upon the experience of the user, and type of substrate. Units assigned to a Hand-Scraping Strategy had high failure rates on final wipe clearance tests and generated more hazardous waste than units assigned to all other strategies except chemical removal.

3. Replacement

Replacement is a strategy of abatement that entails removing components such as windows, doors, and trim that have lead-painted surfaces and installing new or de-leaded components free of lead paint.

Replacement of substrates appears to be the most promising of the removal methods in almost all circumstances. For doors, replacement is less expensive than any other method of removing lead-based paint, and it is comparable in cost to encapsulation. Replacement, while more expensive than encapsulation for substrates other than doors, is cheaper or about as costly as the least expensive of the other removal methods for all substrates except windows. However, in many older homes, the additional cost of window replacement may be recovered in energy savings.

Replacement appears to generate relatively little airborne dust lead and is comparable to encapsulation in this respect.

Replacement works well for almost all substrates and generally improves the quality of a dwelling unit except where the items replaced are very high quality or possess inherent aesthetic value. Units assigned to the Replacement Unit Abatement Strategy performed well on post-abatement wipe clearance tests, where they did about as well as dwelling units assigned to the Encapsulation Unit Abatement Strategy. Replacement methods generated slightly more hazardous waste than encapsulation and enclosure methods, but much less hazardous waste than Hand-Scraping or Chemical Removal Unit Abatement Strategies.

C. Summary

The findings outlined above suggest that the selection of abatement methods for lead-based paint hazards will depend crucially on whether or not encapsulation and/or enclosure abatement methods are believed to be durable and effective abatement methods of treating lead hazards in the long-term.

If encapsulation is determined to be an acceptable method, then the choice of abatement methods is clear. All contaminated substrates would be encapsulated, with the possible exception of doors, which might be replaced. In this way, lead-based paint hazards would be abated at the lowest possible cost, little airborne dust lead would be generated during abatement, abated units would usually pass final clearance wipe tests and there would be a minimum of hazardous waste.

If enclosure is determined to be an acceptable method, but encapsulation is not, the selection of abatement methods is somewhat more difficult. Because both enclosure and replacement generate little airborne dust lead and hazardous waste and because there is little difference between the two methods in terms of success on final wipe clearance tests, the choice should probably be made on the basis of cost. This would lead to a mixed strategy, where enclosure methods would be employed for ceilings, exterior and interior walls, exterior columns and soffits, and replacement methods would be used for baseboards, doors, door frames, windows, window sills and window trim.

One variant on this would be to use hand-scraping with a heat gun for windows rather than replacement, which is more expensive. This would involve a modest increase in airborne dust lead and hazardous waste in return for a decrease in costs.

If neither enclosure nor encapsulation is deemed acceptable because of concerns over durability, then replacement could be the method of choice where feasible. Under these circumstances, chemical removal would have a role on walls, for which neither replacement nor hand-scraping are feasible.

Tabular Summary of Efficacy Factors and Cost Comparisons of Lead-Based Paint Abatement Methods

ENCAPSULATION

Advantages

- Process is quick and easy
- Abatement contractors require little training for application
- Hazardous waste generated is minimal
- A limited amount of capital equipment is required
- Worker protection requirements are minimal (respirators were required during surface preparation)
- Can be carried out both on interior and exterior of abatement unit
- No additional finish work is required
- Can be applied to almost any substrate type and material with proper surface preparation
- A wide variety of products are currently available on the market
- Works well on hard-to-reach areas
- Generates the lowest levels of airborne dust lead during abatement

$ Least expensive of all methods of lead-based paint abatement for all substrates except doors

Disadvantages

- Cannot be used on friction surfaces (e.g., window tracks, door jambs)
- Does not permanently remove the lead --only covers the hazard
- Cannot be applied during adverse weather conditions
- Long-term effectiveness is unknown
- Bonding to lead-based paint surface is sometimes poor
- Further product testing is required
- Quality of products will vary

ENCLOSURE

Advantages

- When installed properly, this method is a very effective alternative to removing the lead-based paint
- May enhance overall appearance of the room/unit
- Generates very little hazardous waste
- Materials are readily available
- Does not create large amounts of dust lead during abatement
- Provides additional thermal insulation on exterior surfaces
- Works well on large, flat surfaces such as ceilings and walls
- Worker protection requirements are minimal
- Generates very little airborne dust lead during abatement

$ Is uniformly more expensive than encapsulating but may be more durable than encapsulation

Disadvantages

- Can only be used on large, flat substrates
- Lead is not removed
- Requires basic carpentry skills
- Seating is critical and must be carefully examined
- May be difficult to install in older units or over masonry surfaces
- There is a potential for buckling and bellowing if not properly installed
- Can be difficult to install in some instances due to surface irregularities and poor existing substrate integrity

CHEMICAL REMOVAL

Advantages

- Effective on a wide variety of substrate types
- Lead is removed permanently
- Application is not difficult and training is moderate
- Various products are readily available
- Leaves the substrate visually clean when used properly
- Only feasible <u>removal</u> method for exterior walls

Disadvantages

- Labor-intensive and requires time for compounds to react
- Very messy--care must be taken to contain the caustic stripper
- Worker protection is especially important
- Waste generated is considered hazardous
- Large potential for damage to surrounding substrates
- If not used properly, may require several iterations to be completely effective
- Can damage substrate if not used properly by experienced personnel
- Highest failure rates on initial sample clearance tests
- Cleanup is extensive
- Requires a moderate range of temperature
- Creates significant amounts of dust lead with respect to most other abatement methods

$ Cost is consistently higher than the costs of removing lead-based paint by hand-scraping or replacement methods.

ABRASIVE REMOVAL

Advantages

- Process leaves substrate clean and in good condition where feasible

Disadvantages

- Often infeasible
- Very labor-intensive method -- large amounts of dust can be generated, requiring worker protection and extensive cleanup
- Application is limited to flat surfaces only, with widths greater than the device
- Does not work well on many materials such as metal, plaster, glass, or gypsum board
- Hard to use in awkward areas (overhead or corners and other detailed areas)

$ Due to the limited application during the demonstration, statistically significant cost data are not available

HAND-SCRAPING REMOVAL WITH A HEAT GUN

Advantages

- Experienced workers can be quick and effective
- Can be used on a variety of surfaces
- Lead-based paint is removed permanently
- Extensive training is not required
- Equipment is inexpensive and readily available

$ Less expensive than replacing windows when only interior or exterior surfaces of the windows require abatement.

Disadvantages

- Very labor-intensive for those with little or no experience
- Creates large amounts of airborne dust lead, more than any other abatement method, and requires strict worker protection in almost all cases
- Paint residue is considered hazardous
- Should not be used on masonry surfaces or on cold metal surfaces
- Care needs to be taken to prevent over-heating of the substrate that could cause a fire

$ More expensive than replacement for most substrates except windows and about the same cost for replacement of baseboards, window sills, and exterior door frames

REMOVAL AND REPLACEMENT

Advantages

- A new, clean substrate results
- Completely abates the lead and hazard
- Can be used on almost all substrates
- Generally improves the quality of a unit
- Does not create significant hazardous waste
- Most promising of the removal methods
- Relatively little airborne dust lead is generated
- $ Least expensive of the removal methods on most substrates except for windows

Disadvantages

- Should not be used where architectural significance will be altered
- Requires skilled tradespeople
- $ More costly than encapsulation for all substrates except for doors

GLOSSARY

ABATEMENT - A comprehensive process of eliminating exposure to lead paint and lead dust which must include testing, and measures for worker protection, containment of dust and debris, cleanup and disposal of waste, and clearance testing.

ABATEMENT CONTRACTOR - Any business entity or person performing the actual abatement for a lead abatement project.

ABRASIVE REMOVAL - A method of abatement that entails the removal of lead-based paint using mechanical removal equipment logically fitted with a high efficiency particulate accumulator (HEPA) dust collection system.

AREA AIR SAMPLES (for sampling dust lead) - Air samples collected from an area in which abatement activity is being conducted. The samples are collected with an area sampling pump pulling a measured volume of air/unit of time. Results are presented as micrograms of lead per cubic meter of air.

BIOLOGICAL MONITORING - The analysis of a person's blood and/or urine, to determine the level of lead contamination in the body.

BLANK - A non-exposed sample of the medium used for testing, such as a wipe or filter, which is analyzed like other samples to determine whether (1) samples are contaminated with lead before samples are collected (e.g., at the factory, or at the testing site), (2) the samples are contaminated after sample collection (e.g., during transportation to laboratory or in the laboratory).

CHEMICAL REMOVAL - A method of abatement which entails the removal of lead-based paint using chemical paint strippers.

CONTAINMENT - A process for protecting both workers and the environment by controlling exposures to dust lead and debris created during abatement.

DIRECT READING XRF - An analyzer that provides the operator with a display of lead concentration calculated from the lead "K" x-ray intensity.

EFFICACY - Refers to a method of abatement and is defined as the generalized evaluation of several key factors including the usability of a method, its hazard abatement effectiveness, and the amount of hazardous dust lead generated by a method, measured by air and post-cleanup wipe samples.

ENCAPSULATION - A method of abatement that involves the coating and sealing of surfaces with durable, paint-like coatings specifically formulated to be elastic, long-lasting, and resilient to cracking, peeling, algae and fungus so as to prevent chalking, flaking, lead-containing substances from becoming part of house dust or accessible to children.

ENCLOSURE - The resurfacing or covering of surfaces, and sealing or caulking with durable materials so as to prevent or control chalking, flaking, lead-containing substances from being part of house dust or accessible to children.

ENGINEERING CONTROLS - Measures implemented at the work site to contain, control and/or otherwise reduce exposure to dust lead and debris.

EPA IDENTIFICATION - The unique number assigned by EPA to each generator or transporter of hazardous waste, and each treatment, storage, or disposal facility.

EP TOXICITY - A test, called the extraction procedure, that is designed to identify wastes likely to leach hazardous concentrations of particular toxic constituents into the ground water as a result of improper management. It is a characteristic of hazardous waste. See TCLP.

EXTERIOR WORK AREA - An outdoor porch, stairway or other element of trim or walls on the exterior of a building.

HAND-SCRAPING WITH HEAT GUN - A method of abatement that entails the removal of lead-based paint using a heat gun and hand-scraping tool.

HAZARDOUS WASTE - As defined in RCRA the term "hazardous waste" means a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may:

A. cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible illness, or

B. pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed.

As defined in the regulations, a solid waste is hazardous if it meets one of four conditions:

1. exhibits a characteristic of a hazardous waste (40 CFR Sections 261.20 through 262.24),

2. has been listed as hazardous (40 CFR Section 261.31 through 261.33),

3. is a mixture containing a listed hazardous waste and a non-hazardous solid waste (unless the mixture is specifically excluded or no longer exhibits any of the characteristics of hazardous waste), or

4. is not excluded from regulation as a hazardous waste.

HEPA or High Efficiency Particulate Accumulator - A vacuum fitted with a filter capable of filtering out particles of 0.3 microns or greater from a body of air at 99.97 percent efficiency or greater.

INDUSTRIAL HYGIENIST - A person certified by the American Board of Industrial Hygiene or an industrial hygienist in training, or an individual with equivalent education or experience.

INITIAL SURVEY - A systematic inspection of a dwelling unit by a qualified inspector, using a portable XRF analyzer, atomic absorption spectrometry, or other approved testing techniques, to determine whether a lead-based paint hazard is present.

INTERIOR WORK AREA - A hallway, room or group of rooms in which abatement takes place on the inside of a building.

LANDFILL - A disposal facility or part of a facility where waste is placed in or on land and which is not a land treatment facility, a surface impoundment, or an injection well.

MANIFEST - The shipping document, EPA Form 8700-22, used for identifying the quantity, composition, origin, routing, and destination of hazardous waste during its transportation from the point of generation to the point of treatment, storage, or disposal.

MICROGRAM - One millionth of a gram: 453 grams in one pound, 28,310,000 micrograms in one ounce.

NEGATIVE AIR PROCESS - Creation of negative air pressure within the containment zone by exhausting air from the zone through a HEPA filter.

PERSONAL (BREATHING ZONE) AIR SAMPLES (for sampling dust lead) - Air samples collected from within the breathing zone of a worker, but outside the respirator. The samples are collected with a personal sampling pump, pulling a measured volume of air/unit of time. Results are presented as micrograms of lead per cubic meter of air.

RCRA - Resource Conservation and Recovery Act of 1976. What is commonly referred to as RCRA is an amendment to the Solid Waste Disposal Act of 1965. RCRA was amended in 1980, and most recently, on November 8, 1984.

REPLACEMENT - A strategy of abatement that entails removing components such as windows, doors, and trim that have lead painted surfaces and installing new or de-leaded components free of lead paint.

REPRESENTATIVE SAMPLE - A sample of a universe or whole (e.g., waste sample pile, lagoon, ground water, or waste stream) that can be expected to exhibit the average properties of the universe or whole.

SMALL QUANTITY GENERATOR - A generator who produces less than 100 kg of hazardous waste per month (or accumulates less than 100 kg at any one time) or one who produces less than 1 kg of acutely hazardous waste per month (or accumulates less than 1 kg of acutely hazardous waste at any one time).

SOLID WASTE - As defined in RCRA the term "solid waste" means any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial, mining, and agricultural operations, and from community activities, but does not include solid or dissolved material in domestic sewage, or solid or dissolved materials in irrigation return flows or industrial discharges which are point sources subject to permits under the Clean Water Act, or special nuclear or byproduct material as defined by the Atomic Energy Act of 1954.

STORAGE - The holding of hazardous waste for a temporary period, at the end of which the hazardous waste is treated, disposed of, or stored elsewhere.

SUBSTRATE - The material that is coated, usually composed of wood, plaster, or metal, including items such as door frame, window trim, walls, baseboards, etc.

SURFACE - The outer or topmost boundary of a substrate.

TAKE-OFFS - A term used to represent measured values taken from substrates to be abated of lead-based paint hazards.

TCLP - Toxic Characteristic Leaching Procedure; see EP Toxicity.

TSP - Acronym for trisodium phosphate.

u; MICROGRAM - The prefix "micro-" means "1/1,000,000 of" (a microgram is 1/1,000,000 of a gram or 1/1000 of a milligram.

UNIT ABATEMENT STRATEGY - A research tool that is a set of rules describing how the generic methods of abatement are to be assigned to each type of substrate, used for purposes of the HUD Lead-Based Paint Abatement Demonstration.

WIPE TEST - A test used to determine the concentration of lead particles; used to determine whether clearance levels for lead abatement have been achieved. For the demonstration a wipe test usually assimilated the dust from a measured surface area of about one square foot and then was laboratory analyzed to determine the quantity of lead contained in that area.

WORK PRACTICE CONTROL - See definition of engineering control.

XRF ANALYZER - An instrument that determines lead concentration in milligrams per square centimeter (mg/cm^2) using the principle of x-ray fluorescence. Two types of XRF analyzers are used, direct readers and spectrum analyzers.

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