747R93006

APPLICABILITY OF RCRA DISPOSAL REQUIREMENTS TO LEAD-BASED PAINT ABATEMENT WASTES

Final Report

March, 1993

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EXECUTIVE SUMMARY

A study was conducted by the U.S. Environmental Protection Agency's (EPA's) Office of Pollution Prevention and Toxics, in response to a request from Congress (FY 1990 Appropriations Conference Report on HUD and Independent Agencies [Conference Report 101-297, p. 30]) that the Agency prepare a report assuring that Resource Conservation and Recovery Act (RCRA) hazardous waste requirements would not be applied to debris from lead-based paint (LBP) abatement projects. (The term "hazardous" is used throughout this report as a legal definition under RCRA Section 3001 (40CFR Part 261), not as a qualitative toxicological description). The study was conducted in three parts. First, data on waste testing from the Department of Housing and Urban Development's (HUD's) nationwide abatement demonstration project was evaluated to determine the hazardousness as defined under RCRA of various categories of abatement waste. Second, EPA designed and conducted a detailed testing program for two important categories of waste not adequately tested in the HUD demonstration (large solid debris, and protective plastic sheeting). Third, waste disposal experience of HUD's contractor for the demonstration project was examined to obtain preliminary estimates of the volume of hazardous waste generated, and the cost of disposing of these wastes.

There are three categories of waste produced in large volume during lead-based paint abatement. These are:

1. Filtered wash-water;
2. Solid debris, such as old woodwork, plaster, windows, doors, and similar bulky components;
3. Plastic sheets and tape used to cover floors and other surfaces.

Filtered wash-water was found to be non-hazardous, and may be disposed of according to State and local requirements. Solid debris was generally found to be hazardous only if the lead level in the paint, as measured in the laboratory by Atomic Absorption Spectrometry (AAS), exceeded approximately 4.0 milligrams per square centimeter (mg/cm^2). Specifically, 5 of 6 samples tested (83%) whose paint AAS lead level exceeded 4.0 mg/cm^2 failed the Toxicity Characteristic Leaching Procedure (TCLP) test for lead toxicity. Conversely, only 1 of 14 (6%) with paint AAS lead level below 4.0 mg/cm^2 failed the TCLP test. Measurements of paint lead level by field X-Ray Fluorescence (XRF) were poorly correlated with TCLP results. Due to the limited number and non-random selection of samples tested, the results for solid debris are suggestive only, and require confirmation in a larger study before they can be used as a basis for EPA policy.

Plastic sheeting was found to be hazardous if certain abatement methods were used. Based on the samples available to us, when a heat gun was used for paint removal, the plastic sheeting was hazardous. However, it should be noted that, because of the limited availability of samples, all plastic sheeting samples tested came from a single dwelling; it would be desirable to confirm the above finding by testing additional plastic samples from other dwellings where a heat gun was used. When encapsulation (use of flexible wall covering systems of a reinforced fiber type that form a secure bond with the substrate) or enclosure (covering LBP-contaminated surfaces with wood paneling, gypsum board, or fabricated exterior enclosure systems of aluminum, vinyl or wood) were used, the plastic was sometimes marginally hazardous. When other methods were used, in particular removal and replacement of contaminated components, the plastic was non-hazardous. It should be noted that, although the above findings are indicative of whether or not various types of abatement waste are likely to be hazardous, waste generators are ultimately responsible under EPA regulations for the proper characterization and disposal of their waste.

There are several other categories of waste commonly produced during abatement, such as sludges, paint chips, mops and rags, etc. Many of these categories are often hazardous. However, in many cases the volumes of waste involved may be sufficiently small that it is cost effective to dispose of them as hazardous, rather than incurring the expense of testing for lead toxicity. This trade-off should be made by abatement contractors on a case-by-case basis.

In HUD's demonstration project, an average of 217 lbs of hazardous waste was generated per housing unit in the three cities for which data was available, with an average disposal cost of $255 per unit. These estimates do not include hazardous-waste-related costs incurred directly by the abatement contractor, such as management time and TCLP testing costs. They are also low to the extent that large solid debris and plastic sheeting were not generally treated as hazardous by the contractor. The impact of this cannot be quantified at present, because records were not kept on volumes of solid debris and plastic sheeting generated in the HUD demonstration. The estimates of hazardous waste disposal costs are high to the extent that unrealistically large amounts of paint were stripped in the demonstration. This is because the demonstration was designed to evaluate a range of potential abatement methods, and not necessarily to mirror real-world abatement practices. Because stripping of paint is extremely labor-intensive and costly, and not often necessary, it is unlikely to be adopted in practice on a large scale, except for historical properties.

1.0 INTRODUCTION AND METHODS

1.1 PURPOSE OF THE REPORT

Under the Lead-Based Paint Poisoning Prevention Act (LBPPA), as amended by the Housing and Community Development Act of 1987, and the Stewart B. McKinney Homeless Assistance Amendment Act of 1988, the Department of Housing and Urban Development (HUD) is mandated to require inspection, by 1994, for lead-based paint (LBP) in a random sample of dwellings and common areas in pre-1978 public and Indian family housing. Under the statute, paint with lead levels exceeding 1.0 mg/cm^2 constitutes a hazard requiring abatement. In addition, HUD was required to submit to Congress a "comprehensive and workable plan" for addressing the LBP hazard in privately-owned housing (Comprehensive and Workable Plan for the Abatement of Lead-Based Paint in Privately Owned Housing: A Report to Congress, HUD (December 7, 1990).

The large scope of the LBP problem, combined with increasing public health concern about the effects of even low-level lead exposure to young children, indicates the potential for a major nationwide abatement effort in the next 10 years. Many LBP abatements, especially those involving removal and replacement of doors, windows and trim painted with LBP, produce large quantities of solid waste containing lead in varying concentrations. Congress is concerned that the potential applicability of hazardous waste requirements under the Resource Conservation and Recovery Act of 1976 (RCRA) to LBP abatement waste may substantially increase the cost of abatement, and has requested a report from EPA "assuring that hazardous waste requirements will not be applied to debris from lead-based paint abatement projects".

The purpose of the present report is to describe research conducted by EPA to:

(1) determine which "typical" forms of lead-based paint debris would require classification as RCRA hazardous waste; and,

(2) provide guidance for persons conducting lead paint abatements as to which types of waste may be disposed of as normal construction debris, and which must be presumed to be hazardous waste unless specifically tested and found not to meet RCRA criteria.

1.2 RCRA BACKGROUND

RCRA is the basic Federal law governing waste disposal. A key distinction under RCRA is that between solid waste and hazardous waste. Solid waste is regulated by the States under RCRA, subject to minimum Federal standards. By contrast, RCRA establishes a "cradle-to-grave" system for the management of hazardous waste from generation to ultimate disposal. Packaging requirements for hazardous waste under RCRA are described in 40CFR, Parts 173, 178, 179, and 262 Subpart(c).

Under RCRA, a waste may be hazardous either because of its characteristics or because it is specifically listed as hazardous. Listed hazardous wastes are unlikely to be generated in lead-based paint abatements. The four hazardous characteristics are ignitability, corrosivity, reactivity, and toxicity. Of these, corrosivity and toxicity are of most concern in lead paint abatements. Chemicals used for paint stripping are typically corrosive. With regard to toxicity, lead is the constituent of concern in the waste. A waste is defined as exhibiting the toxicity characteristic for lead if a standard testing procedure results in the extraction of lead from the waste at a concentration equalling or exceeding 5 milligrams per liter (parts per million). This level is 100 times the National Interim Primary Drinking Water Standard for lead.

Prior to March 1990, the Extraction Procedure Toxicity Test (EP-TOX) was used to determine whether a waste was hazardous under RCRA. This testing procedure was designed to mimic the leaching action in a landfill. The March 1990 revision of the RCRA toxicity characteristic (TC) replaced the EP-TOX with the Toxicity Characteristic Leaching Procedure (TCLP). The TC became effective on September 25, 1990. However, small-quantity waste generators could continue to use the EP-TOX until March 1991. The TCLP is considered to be a more reliable and reproducible test than the EP-TOX.

Under RCRA, generators of waste are allowed to rely on the results of prior testing or experience, or knowledge of the waste or process generating the waste, in evaluating their waste to determine if it is hazardous. Thus, the research reported here is a first step towards a determination whether the wastes generated in lead-based paint abatement projects fall under the RCRA definition of hazardous waste.

1.3 STUDY DESIGN AND RESULTS

The waste samples evaluated in this study, and some of the testing results, were provided to EPA by HUD from its Demonstration Project ("the Demo") on lead-based paint abatement methods. The HUD Demo involved the application of a wide range of abatement methods to vacant Federal Housing Administration (FHA) housing in 5 cities nationwide (Washington, D.C./Baltimore; Indianapolis; Denver; Birmingham AL; and, Seattle/Tacoma). The purpose of the Demo was to gather reliable data on the cost and applicability of existing abatement techniques to public and private housing. As required under RCRA, the contractor for the Demo, Dewberry & Davis, evaluated waste from the abatements for lead toxicity. Results of EP-TOX testing conducted in the Demo were made available to EPA, and used as the basis for an initial evaluation of the hazardousness of abatement waste.

The generally non-hazardous categories of waste were: filtered wash-water; disposable work clothes and respirator filters; and rugs and carpets. The categories that were mixed, with both hazardous and non-hazardous samples, were: paint chips; HEPA vacuum debris, dust from air filters, and paint dust; sludge from stripping; unfiltered liquid waste; and rags, sponges, mops, HEPA filters, air monitoring cartridges, scrapers, and other materials used for testing, abatement, and clean-up. The volume of these wastes is expected to be relatively small. A cost effective approach may be to treat all wastes in the mixed hazard categories as subject to RCRA requirements; a discussion of the trade-off involved is presented in Section 2. Finally, two categories, solid components such as doors and window frames, and, plastic sheeting used to protect floors and contain dust during abatements, had insufficient testing data from the Demo.

The second stage of the research was a carefully designed testing program to evaluate solids and plastic sheeting. These categories of waste are the highest volume categories produced during abatement, with the exception of filtered wash-water. Because of the change from EP-TOX to TCLP, EPA decided to test the solids and plastic sheeting using the TCLP only.

A total of 30 solids and 30 plastic samples were selected by EPA from preliminary lists of available waste from HUD Demo sites. A quota of solids samples was specified in each of 4 classes based on available measurements of paint lead levels taken in the field by Dewberry & Davis. In this way, a representation of the range of paint lead levels encountered in practice was obtained. The plastic sheeting samples were selected to represent both the range of abatement methods used, and the range of lead levels encountered in the rooms from which the samples were taken. In practice, it was not possible to obtain all the samples requested by EPA, due to the constraints of the Demo schedule. The final sample consisted of 20 solids and 32 plastic samples, including substitutions made by HUD. It was not possible to randomly assign samples to dwelling units. For example, all plastic samples for the "Heat Gun" method of abatement came from a single dwelling. The confounding of dwelling unit with abatement method adds an unknown bias to the study. Nevertheless, EPA evaluated the final set of samples and concluded that the design objectives had been adequately met for the study to proceed.

Six out of twenty solid samples (30%), and twelve out of thirty two plastic samples had TCLP test results exceeding the RCRA standard of 5 mg/l for lead. The data indicated that wood debris samples are expected to exceed the 5 mg/l level on the TCLP whenever the lead level in the paint on the surface exceeds 4 mg/cm^2, as measured by a laboratory test. Paint lead measurements using an X-Ray Fluorescence detector (XRF), the usual method of field screening for lead, were not found to reliably predict the TCLP result. For plastic samples, the data indicated that plastic sheeting used in abatements conducted by the "Heat Gun" method of paint removal generally fail the TCLP test. Some samples from the "Enclosure" (covering LBP-contaminated surfaces with wood paneling, gypsum board, or fabricated exterior enclosure systems of aluminum, vinyl or wood) and "Encapsulation" (use of flexible wall covering systems of a reinforced fiber type that form a secure bond with the substrate) methods produced TCLP results slightly in excess of 5 mg/l, but never above 5.4 mg/l. These marginally hazardous results do not suffice to definitively determine the hazardous waste status of plastic sheeting from the "Enclosure" and "Encapsulation" abatement methods; considerably more data would be required to do so. Finally, no plastic sheeting samples from the "Chemical Removal", "Remove/Replace", or "Abrasive Removal" abatement methods triggered the TCLP test.

The third stage of the research was a brief evaluation of volumes and disposal costs of hazardous wastes in the HUD Demo. In the 3 cities for which data is available (Birmingham, Denver, and Seattle/Tacoma), an average of 217 lbs of hazardous waste was generated per housing unit, with an average disposal cost of $255 per unit. These per-unit estimates are low to the extent that large solid debris and plastic sheeting were not generally treated as hazardous by the contractor. They were disposed of in a solid-waste landfill and hence no hazardous waste disposal costs were incurred. The per-unit hazardous waste disposal cost estimates are high to the extent that far more stripping of paint was carried out in the Demo than would likely occur in practice (stripping of paint is extremely labor-intensive, costly, and not often necessary).

1.4 REPORT ORGANIZATION

Section 2.0 of the report presents a detailed discussion of the analysis of EP-TOX results from the HUD Demo. Section 3.0 describes the follow-on testing program for solids and plastic sheeting designed and conducted by EPA. Section 4.0 presents a brief discussion of waste volumes and disposal costs encountered in the Demo. Section 5.0 presents the conclusions of the study.

2.0 TOXICITY TESTING DATA FROM THE HUD DEMO

As part of the HUD Demo, 80 abatement waste samples from 5 cities were analyzed for lead by EP-TOX. Appendix A presents the test data, sorted by waste category and lead concentration in the extract. For each sample, the following data is given:

1. Numerical sample identifier (SAMPLE ID)
2. Sample description
3. Lead concentration in EP-TOX extract (ppm) (LEAD)
4. Waste category (CAT)
5. City identifier (CITY)
6. Location (address) identifier (LOC).

The waste categories are based on the nine waste categories in Chapter 11 of "Lead-Based Paint: Interim Guidelines for Hazard Identification and Abatement in Public and Indian Housing" ("the Guidelines"), published by HUD in the Federal Register on April 18, 1990. For this report, the waste category "rugs and carpets" has been added, and the Chapter 11 category "liquid waste" has been divided into "filtered wash-water" and "unfiltered liquid waste." Thus, there are eleven waste categories in this report. The purpose of waste categorization is to facilitate the evaluation of waste as hazardous/non-hazardous, and to reduce the amount of testing which needs to be performed. RCRA regulations do not require testing of waste when prior experience or knowledge of the generator or disposal firm is sufficient to make a determination of hazardousness. The use of appropriate waste categories makes prior testing experience much easier to apply.

Each of the eleven waste categories may be classified in one of three ways based on the EP-TOX lead testing data from the HUD Demo. The following waste categories were found to be generally non-hazardous:

a. Filtered wash-water.
b. Disposable work clothes and respirator filters.
c. Rugs and carpets.

Therefore, abatement contractors may dispose of waste in these categories according to State and local solid waste regulations. However, contractors should be sure to check with local authorities before flushing filtered wash-water down storm sewers.

The following categories were found to be hazardous in at least 50% of tested cases:

a. Paint chips.
b. High Efficiency Particle Air (HEPA) vacuum debris, dust from air filters, paint dust.
c. Sludge from stripping.
d. Unfiltered liquid waste such as wash water from general cleanup or from decontaminating surfaces after solvents have been used; unfiltered liquid waste from exterior blasting.
e. Rags, sponges, mops, HEPA filters, air monitoring cartridges, scrapers, and other materials used for testing, abatement and cleanup.

Abatement-specific conditions such as, for example, the level of lead in the paint or the matrix holding the lead, will affect whether or not waste in these categories must be treated as hazardous waste under RCRA regulations. The abatement contractor, or disposal firm, may choose to test the specific waste from their project to determine whether it is hazardous. However, the above categories will generally contain relatively small volumes of waste, so that a more cost-effective solution may be to simply treat all the waste in these categories as subject to RCRA hazardous waste requirements.

The trade-off between TCLP testing and simply disposing of the waste as hazardous without testing depends on the cost of testing, the cost of disposal, and the likelihood that the waste will fail the TCLP test. As an example, EPA's Office of Solid Waste estimates the cost of a TCLP test as $175. The average cost of hazardous waste disposal in the HUD Demo was $1.18 per lb, see Section 4 of this report. Finally, the probability that the above wastes will fail the TCLP is approximately 50%. Thus, if W is the number of lbs of waste expected in a particular category, TCLP testing will save money provided $175 + (0.5)*(1.18)*W < 1.18*W$, i.e., provided $W > 297$. Thus, for the hazardous waste disposal costs experienced in the Demo, the break-even point for testing is approximately 300 lbs of waste in a single category (e.g., paint chips). The break-even point depends on the cost of hazardous waste disposal. Independent estimates developed by EPA's Office of Solid Waste (OSW) show a range of disposal costs from $0.18 to $1.03 per pound for off-site immobilization of the waste followed by disposal (the most likely disposal method for waste from lead-paint abatements). These estimates translate to a break-even point for testing of between 340 pounds and 1940 pounds of hazardous waste. OSW's disposal cost estimates are lower than the actual costs experienced by HUD in the Demo. The differences between the costs are discussed in Section 4.

The category "solvents and caustics" was not tested. However, the wastes in this category are likely to be hazardous by virtue of corrosiveness. Quantities of waste in this category are expected to be relatively small, and again a cost effective solution may be to treat these wastes as hazardous. The abatement contractor should evaluate this trade-off on a case-by-case basis, using the methodology outlined above.

The following categories had <u>insufficient testing information</u> from the HUD Demo:

a. "Solids", i.e., old woodwork, plaster, windows, doors, and similar bulky components removed from the building.

b. Plastic sheets and tape used to cover floors and other surfaces during LBP removal.

Aside from filtered wash-water, these categories contain the largest-volume wastes expected to be encountered in LBP abatements. In practice, the abatement strategy of choice for lead-painted windows, doors, and wooden trim will often be removal and replacement with new components, particularly when abatement is carried out as part of a larger renovation project. Only for houses of historic value is the removal of the paint from these components by stripping likely to be adopted as an abatement method on a large scale. Whatever method of abatement is used, large volumes of plastic sheeting will be used to contain dust and debris.

Because of the importance of these waste categories, EPA designed and carried out a testing program, described in the next section of the report. Since the TCLP replaced the EP-TOX test for all generators in March 1991, only TCLP testing was conducted on these additional solid and plastic samples.

3.0 TCLP TESTING PROGRAM FOR SOLIDS AND PLASTIC SHEETING

3.1 TCLP TESTING OF SOLIDS

The original design for TCLP testing of solids called for testing a total of 30 samples, drawn from specified ranges of XRF lead levels, as shown in Table I. The goal of this design was to conduct TCLP testing on samples with a wide range of XRF levels, in order to facilitate the determination of the XRF level which may trigger a positive TCLP. Unfortunately, EPA was able to obtain from the HUD Demo only 20 samples from a total of 10 dwellings, as described in detail in Appendix B. The inability to select samples randomly from dwellings adds an unknown bias to the evaluation. The selected samples are summarized by XRF level in Table I. Even though only two thirds of the requested samples were obtained, EPA decided to proceed with the TCLP testing for two reasons. First, there was an urgent need for information, even if incomplete, on the applicability of RCRA requirements to solids. Second, the available samples were concentrated in the higher ranges of XRF lead levels which are most likely to trigger a positive TCLP.

TABLE I: DESIGN FOR TCLP TESTING OF SOLIDS

XRF Level (mg/cm^2)	Number of Samples (Original Design)	Number of Samples Available
1 - 2	5	0
2 - 4	10	5
4 - 8	10	8
>8	5	5
N/A	0	2

Appendix B presents the following information for each sample:

a. Numerical sample identifier

b. Unit address
c. Substrate from which the sample was taken
d. Location of the sample within the unit
e. XRF lead measurement on the substrate from which the sample was taken (where available).

In 2 cases, no XRF measurement was available. Thus, 18 of the 20 samples have an XRF lead measurement. In addition to the TCLP test, chemical analysis of a sample of paint from each solid was conducted to determine the concentration of lead in the paint, both by weight and on an area basis.

3.2 RESULTS OF TCLP TESTING OF SOLIDS

Table II shows the TCLP testing results for the 20 solids samples tested, sorted in decreasing order of the lead concentration in the TCLP extract. The data is taken from the report "Hazardous Waste Support: Report for Work Assignment No. 21, Lead Abatement Waste Analysis", prepared for EPA's Office of Solid Waste by Science Applications International Corporation (SAIC) under EPA Contract No. 68-W9-0011 (July 31, 1990). The first column of the table shows the sample identifier from Appendix B. The second column, labelled "LAB LEAD (mg/cm^2)", shows the area concentration of lead in the paint on the sample, in units of milligrams per square centimeter, as measured in the laboratory. The area of the painted surface was first measured and then the concentration of lead on the sample was measured using AAS. For one sample, ID # 105, the area concentration is reported as a range. The analytical laboratory experienced difficulty determining the area of paint on this sample, due to extreme weathering of the sample. The third column, labelled "LAB LEAD (mg/kg)", shows the concentration of lead in the paint by weight, as measured in the laboratory. The units of this measurement are milligrams per kilogram, i.e., parts per million. The fourth column of the table, labelled "XRF LEAD (mg/cm²)", shows the area concentration of lead in the paint, as measured in the field by an X-Ray Fluorescence instrument. For two samples, ID #'s 102 and 104, no XRF measurement was available. Finally, the last column presents the result of the TCLP test on the sample, as the concentration of lead in the TCLP extract, in units of milligrams per liter (parts per million). Two of the results, for sample ID #'s 102 and 108, were below the detection limit of the procedure.

TABLE II: TCLP TESTING RESULTS FOR SOLIDS SAMPLES

SAMPLE ID	LAB LEAD (mg/cm^2)	LAB LEAD (mg/kg)	XRF LEAD (mg/cm^2)	TCLP LEAD (mg/l)
105	3.4 - 5.1	94800	5.9	21
101	9.3	103000	6.1	13
112	5.3	50400	9.7	12
120	19.4	171000	9.4	10
119	19.4	174000	9.4	9.5
107	3.9	24300	2.8	5.4
109	6.2	96500	8	4.8
113	0.86	32700	6.8	4.5
111	0.72	5360	5.3	4.1
110	0.028	580	8.2	3.4
114	2.8	40400	4.6	2.5
118	3.9	43800	4.8	2.3
104	0.38	21700	N/A	2.1
106	3.4	98200	8.7	1.2
116	2.9	27400	4.8	1.0
115	0.54	6240	3.1	0.9
103	2.2	20400	3.7	0.8
117	1.1	15300	3.1	0.4
108	0.016	670	3.1	<0.3
102	0.12	2430	N/A	<0.3

Six of the twenty samples analyzed (30%) exceeded the RCRA toxicity characteristic limit of 5 mg/l lead in the TCLP extract. It is clear from the table that the higher TCLP results are associated with higher area concentrations of lead, as measured in the laboratory. Figure I is a plot of area lead concentration versus TCLP result. For plotting purposes, the area lead concentration for sample # 105 has been treated as the average of the reported range, and the TCLP results below the detection limit of 0.3 mg/l have been set to 0.3 mg/l. The plot confirms the impression given by the table. Of the 6 samples with paint AAS lead level exceeding 4.0 mg/cm^2, 5 (83%) failed the TCLP. Conversely, only 1 of 14 (6%) with AAS level below 4.0 mg/cm^2 failed TCLP. The data suggests the following rule of thumb: <u>TREAT AS HAZARDOUS WASTE ALL SOLID DEBRIS WITH AREA LEAD CONCENTRATION, AS MEASURED IN THE LABORATORY, EXCEEDING 4.0 mg/cm^2.</u> However, this rule is based on limited data of doubtful representativeness. It requires confirmation in a larger study before being used as a basis for EPA policy with respect to debris from lead paint abatements.

For field testing purposes, it would be very convenient if XRF measurements of lead concentration, rather than laboratory measurements, could be used as a predictor of hazardous waste status. This is because extensive XRF testing is routinely conducted prior to abatement. Unfortunately, the data reported here does not indicate a sufficiently strong relationship between XRF and laboratory lead measurements for practical use. Figure II is a plot of TCLP result versus XRF lead measurement for the 18 samples for which an XRF measurement was available. Clearly, the relationship between the two variables is weak. For example, XRF measurements as high as 8.7 mg/cm^2 are associated with low TCLP results. Conversely, one XRF measurement of 2.8 mg/cm^2 has a TCLP result of 5.4 mg/l. There are two possible causes for the weaker relationship observed between XRF measurements and the TCLP than between laboratory measurements and the TCLP. First, XRF

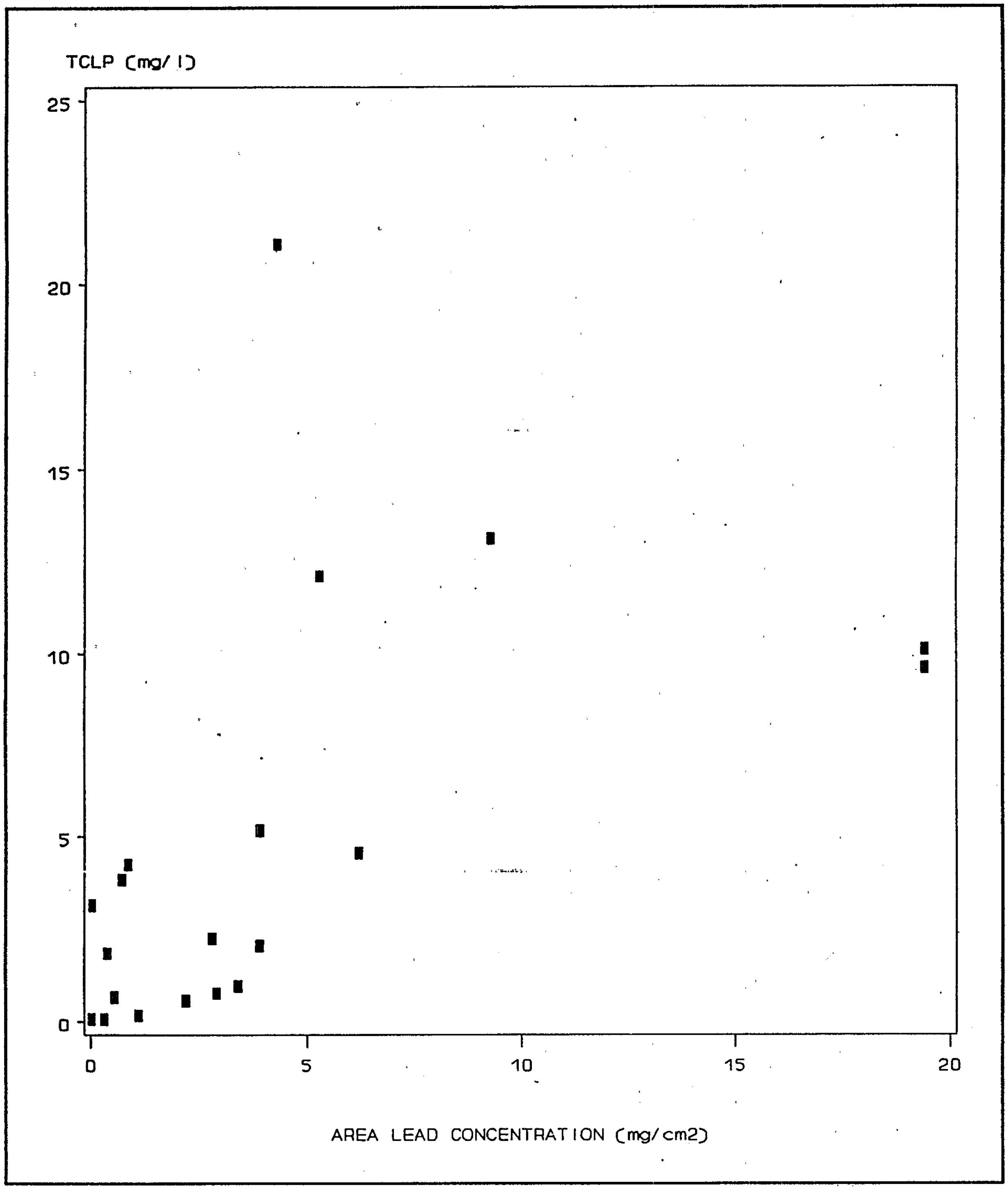

Figure I. Plot of TCLP Result for Solids Samples Against Paint Lead Concentration on an Area Basis, as Determined by Laboratory Analysis

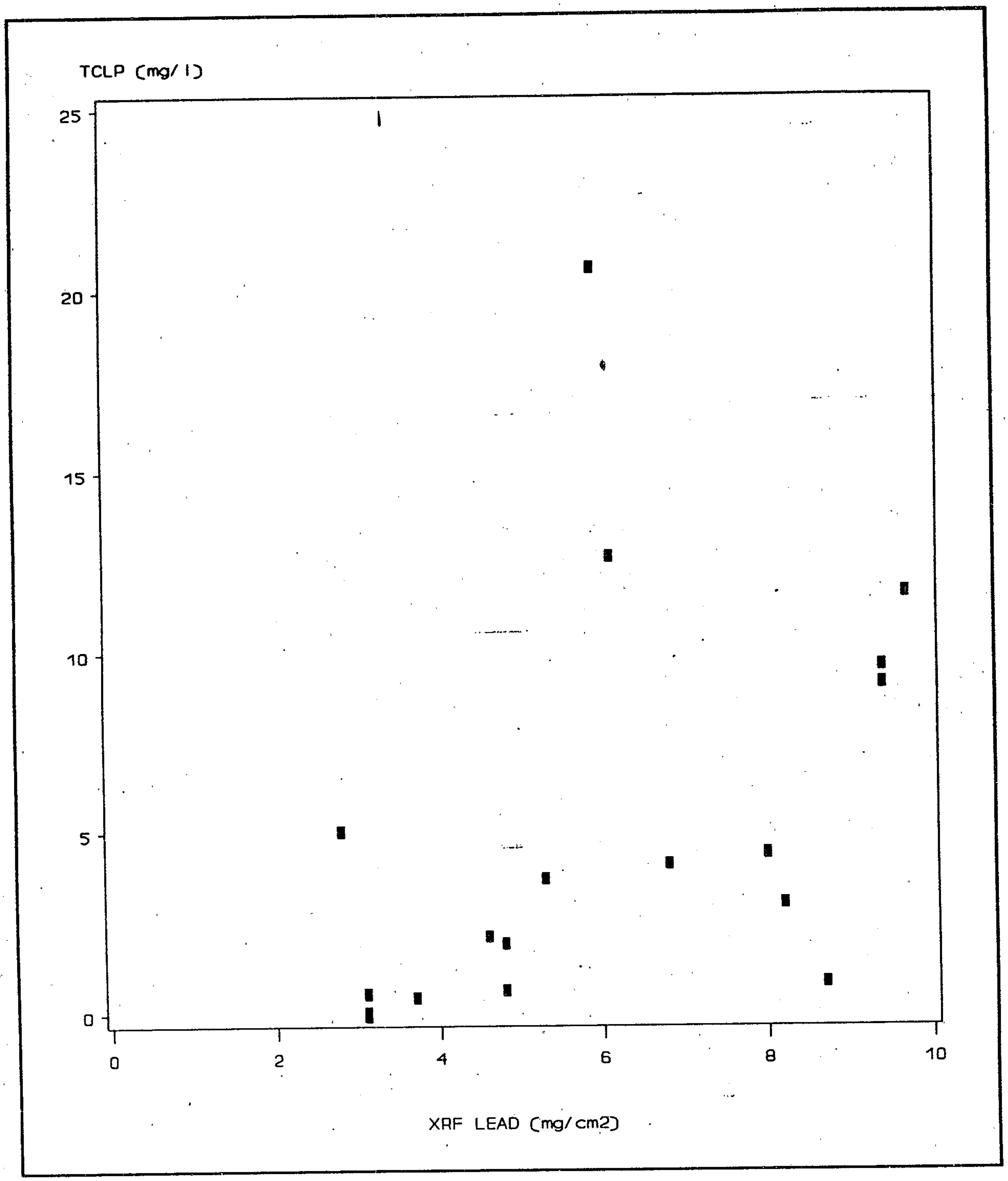

Figure II. Plot of TCLP Result for Solids Samples Against Paint Lead Concentration on an Area Basis, as Determined by XRF Analyzer

measurements are known to be much less accurate than laboratory measurements of lead in paint. Second, the XRF measurement reported for a sample was not necessarily taken on the specific piece of debris analyzed by the TCLP. For example, the TCLP analysis for debris from a door might have been conducted on a piece of the door some distance from where the XRF measurement was taken. Variations in paint thickness therefore contribute further to inaccuracies in the XRF measurement for our purposes.

3.3 TCLP TESTING OF PLASTIC SHEETING

A large choice of potential samples of 6-mil plastic floor covering from units in the HUD Demo was made available to EPA. From these, EPA specified 30 sampling locations from each of which 10 square feet of plastic, weighing approximately 100 grams, were to be taken. Of the specified samples, 20 were actually available. An additional 12 were provided by HUD as substitutes. Appendix C presents a summary of the plastic samples. For each sample, the following information is given:

a. Numerical sample ID (ID)
b. Address of the unit
c. Selection code (SEL); ORG = original sample actually obtained; SUB = HUD substitution; N/A = originally requested sample which was unavailable
d. Room from which sample was taken (ROOM)
e. Average lead level of tested surfaces in the room (mg/cm^2) (MEAN)
f. Number of surfaces tested in the room (N)
g. Abatement method.

The specification of the 30 sampling locations was guided by two considerations. First, EPA wanted to obtain samples from each of the abatement methods used in the Demo, but especially from chemical removal and heat gun methods, because it was felt that these were the methods most likely to contaminate the plastic and trigger a positive TCLP result. Second, EPA wanted to take samples from rooms with higher levels of lead. The average XRF measurement taken in the room was used as a proxy for the amount of lead in the room. Rooms with the highest average level within each abatement method were specified for sampling.

The 32 samples actually obtained represent an acceptable approximation to the design criteria stated above. Of the abatement methods, only removal and replacement is poorly represented. There is adequate representation of the higher room lead levels, even though the substitutes generally come from rooms with less lead. However, the abatement method used is confounded with the dwelling, in the sense that the samples for most methods come from only one or two dwellings. For example, all heat gun samples come from the same dwelling. This confounding introduces an unknown but unavoidable bias into the study results.

3.4 ANALYSIS OF TCLP TESTING RESULTS FROM PLASTIC SAMPLES

Table III shows the results of the TCLP testing of the plastic samples, again taken from the SAIC report previously referenced. The variables reported are as follows. "ID" is the sample identifier given in Appendix C. "TCLP" is the result of the TCLP test procedure, in milligrams of lead per liter in the extract. "ROOM LEAD" is the arithmetic mean of all XRF lead measurements in the room from which the plastic sample was taken, in milligrams per square centimeter. "PRIMARY METHOD" is the primary method of abatement applied to surfaces in the room, as reported by Dewberry & Davis, the contractor for the HUD Demo. "SECONDARY METHOD" is the secondary method of abatement applied, whenever more than one method was used in the room. The determination of primary versus secondary method was based on the number of surfaces abated by each method.

TABLE III: TCLP TESTING RESULTS FOR PLASTIC SAMPLES

ID	TCLP (mg/l)	ROOM LEAD (mg/cm²)	PRIMARY ABATEMENT METHOD	SECONDARY METHOD
1	< 0.3	2.6	Encapsulation	
2	0.47	3.2	Encapsulation	
3	5.4	5.6	Encapsulation	
4	1.2	9.4	Encapsulation	
5	<0.3	3.4	Encapsulation	Enclosure
6	0.41	8.6	Encapsulation	Enclosure
7	<0.3	5.4	Abrasive Removal	
8	0.67	9.4	Abrasive Removal	
9	<0.3	9.6	Abrasive Removal	
10	8.4	2.6	Heat Gun	
11	15	6.9	Heat Gun	
12	17	7.4	Heat Gun	
13	28	8.7	Heat Gun	
14	12	8.8	Heat Gun	
15	46	8.9	Heat Gun	
16	40	9.3	Heat Gun	
17	5.9	0.4	Enclosure	
18	3.1	1.1	Heat Gun	Chemical Removal
19	60	8.3	Heat Gun	Enclosure
20	0.78	1.3	Chemical Removal	
21	0.44	1.4	Chemical Removal	
22	2.1	1.5	Chemical Removal	
23	0.98	1.6	Chemical Removal	
24	0.67	1.8	Chemical Removal	
25	0.69	2.8	Chemical Removal	
26	8.3	1.3	Enclosure	Heat Gun
27	0.41	2.2	Enclosure	
28	< 0.3	7	Enclosure	Encapsulation
29	< 0.3	2.8	Enclosure	Remove/Replace
30	< 0.3	3.6	Enclosure	Remove/Replace
31	5.4	6.6	Encapsulation	
32	0.5	2.2	Encapsulation	

Twelve of the thirty two samples tested (38%) exceeded the TCLP toxicity characteristic limit of 5 mg/l for lead. Of these, 8 had "Heat Gun" as primary method of abatement, 2 had "Enclosure", and 2 had "Encapsulation". The 8 "Heat Gun" samples were the highest values reported. The higher of the two "Enclosure" samples, with TCLP level of 8.3 mg/l, had "Heat Gun" as secondary method of abatement. The 8 "Heat Gun" samples and the 2 "Enclosure" samples all came from the same housing unit, whereas the 2 "Encapsulation" samples were from distinct units different from the unit for the other 10. The TCLP result for each of these, 5.4 mg/l, was the smallest of those exceeding 5 mg/l. The tentative conclusion to be drawn from the data appears to be that plastic sheeting should be treated as hazardous waste whenever the "Heat Gun" method of abatement is used, and that there is a potential for triggering RCRA hazardous waste requirements when "Enclosure" or "Encapsulation" are used. Contrary to prior expectation, the "Chemical Removal" abatement method resulted in very low TCLP results for the plastic sheeting.

Further analyses were conducted to explore the quantitative relationship between the level of lead in the room, the abatement method used, and the result of the TCLP test on the plastic sheeting. Figure III shows a plot of TCLP result in mg/l versus "ROOM LEAD" in mg/cm^2. TCLP results below the detection limit of 0.3 mg/l have been set to 0.3 mg/l. The plot is coded according to the primary method of abatement: 1 = Abrasive removal; 2 = Chemical Removal; 3 = Encapsulation; 4 = Heat Gun; 5 = Enclosure. The plot indicates that the "ROOM LEAD" is a poor predictor of TCLP level. Accordingly, a more refined measure of lead in the room was developed from so-called "Part C" data sheets supplied by Dewberry & Davis. The Part C sheets provide, for each component abated, the XRF lead level in the paint (or a laboratory measurement if XRF was not used), and a measure of the total quantity of paint present, in either square feet or lineal feet. The Part C data was used to

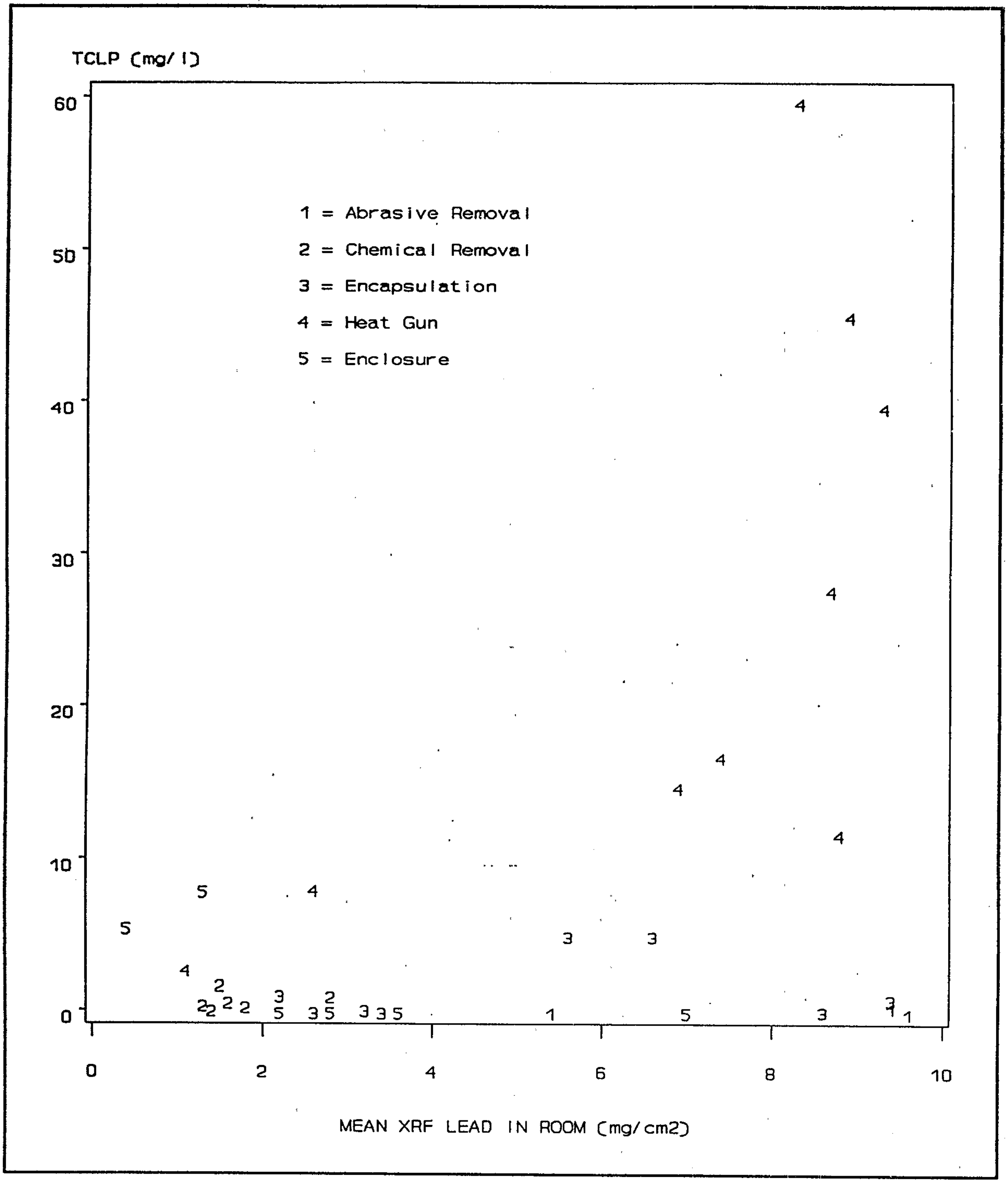

Figure III. Plot of TCLP Result for Plastic Samples Against Average Area Lead Concentration of Abated Surfaces in the Room as Determined by XRF Analyzer (Coded by Primary Abatement Method)

develop an estimate of the total mass of lead abated in each room by each abatement method. The calculations are described below.

The first step was to convert lineal feet to estimated square feet. Table IV shows the conversion factors for lineal feet to square feet developed in discussions with Dewberry & Davis. It should be emphasized that these conversion factors are approximate. The next step was to develop an estimate of total mass of lead on each abated component. The formula used was:

LEAD (kg) = [AREA (sq.ft.)]*[XRF LEAD (mg/cm^2)]*0.000929.

In calculating component areas, it was assumed that doors were painted on both sides, that shelves were painted on one side only, and that 20% of the total area of a window was painted surface. The estimated mass of lead was then totalled in each room by abatement method used. Table V shows the results of these calculations. The columns show the total mass of lead abated in the room by each abatement method. The last column of the table gives the total mass of lead abated in the room by all methods used. Figure IV shows a plot of TCLP result versus total mass of lead abated for the heat gun abatement method. The plot indicates a strong linear relationship (R^2 = 0.78) between TCLP result and

TABLE IV: CONVERSION FACTORS FOR LINEAL FEET TO SQUARE FEET

COMPONENT	CONVERSION FACTOR
Baseboards	1.0 (Baltimore) 0.33 (elsewhere)
Door Frames	1.0
Window Sills	0.33
Window Trim	0.40
Stringers	0.67
Chair Rails	0.17

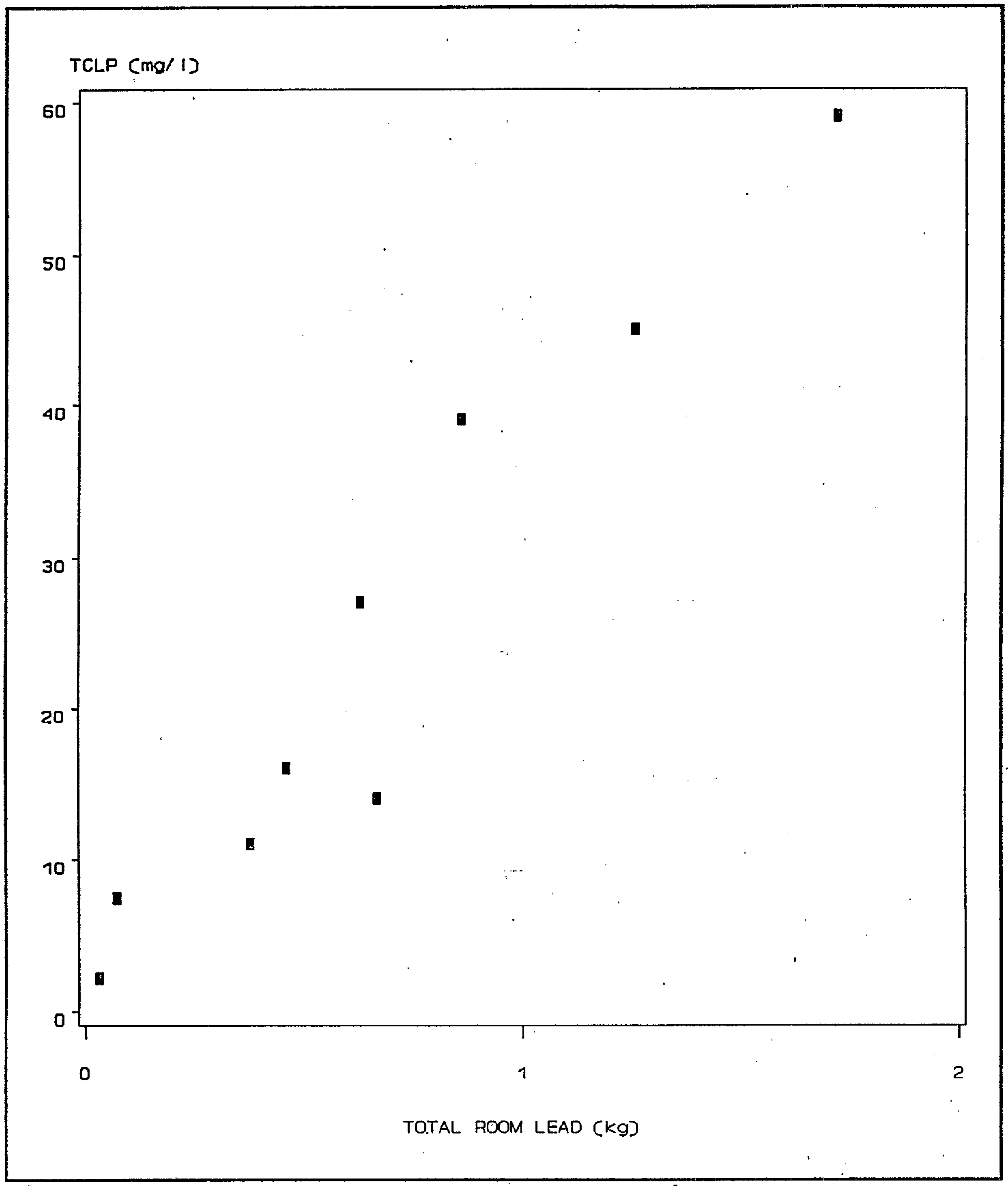

Figure IV. Plot of TCLP Result for Plastic Samples, for "Heat Gun" Abatement Method, Against Total Mass of Lead Abated in the Room, as Determined from XRF Measurements and Surface Dimensions

total lead abated. Figure V is similar to Figure IV, but includes only those samples where "Heat Gun" was <u>not</u> the primary method of abatement. As noted before, abatement methods 3 (encapsulation) and 5 (enclosure) produce higher TCLP levels than methods 1 and 2, but there appears to be only a weak relationship to total lead abated, in contrast to method 4 (heat gun).

To further explore the relationship between mass of lead abated and TCLP result, several regression analyses were run. The results are presented in Appendix D. Two of the regression models fitted have promise as tools for predicting the hazardous waste status of plastic sheeting used in abatements. However, much further testing and refinement would be needed before practical application of any of the regression models.

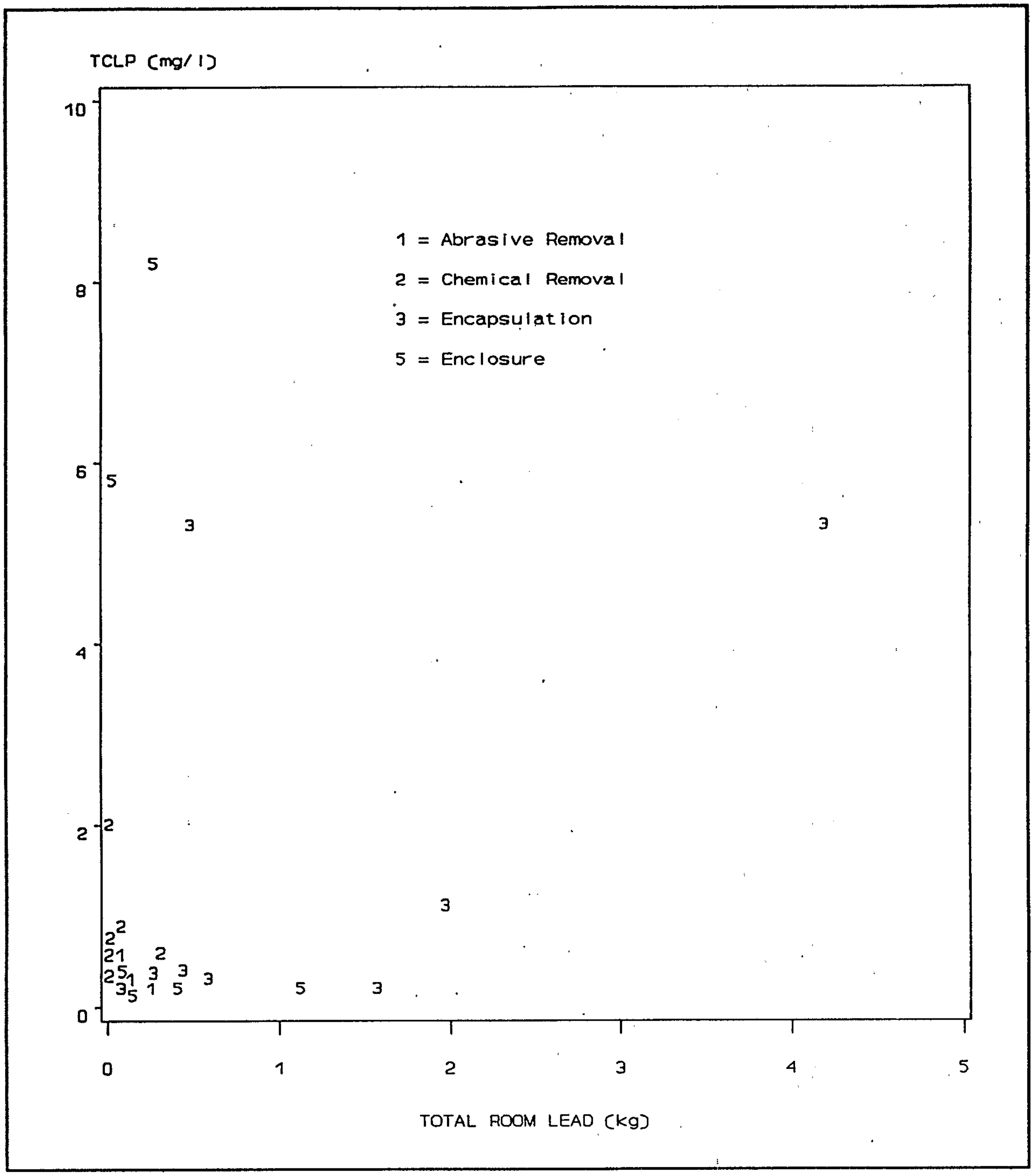

Figure V. Plot of TCLP Result for Plastic Samples Against Total Mass of Lead Abated in the Room, Determined from XRF Measurements and Surface Dimensions, for Samples for which Heat Gun was <u>not</u> the Primary Abatement Method (Coded by Primary Abatement Method)

TABLE V: MASS OF LEAD ABATED (Kg), BY ABATEMENT METHOD

ID	TCLP (mg/l)	Abr Rem	Chem Rem	Encap	Heat Gun	Enclo sure	Rem/ Rep	TOTAL
1	< 0.3	0	0	0.08	0	0	0	0.08
2	0.47	0	0	0.27	0	0	0	0.27
3	5.4	0	0	4.19	0	0	0	4.19
4	1.2	0	0	1.97	0	0	0	1.97
5	< 0.3	0	0	0.75	0	0.82	0	1.57
6	0.41	0	0	0.43	0	0.16	0	0.59
7	< 0.3	0.25	0	0	0	0	0	0.25
8	0.67	0.07	0	0	0	0	0	0.07
9	< 0.3	0.13	0	0	0	0	0	0.13
10	8.4	0	0	0	0.07	0	0	0.07
11	15	0	0	0	0.67	0	0	0.67
12	17	0	0	0	0.46	0	0	0.46
13	28	0	0	0	0.63	0	0	0.63
14	12	0	0	0	0.38	0	0	0.38
15	46	0	0	0	1.26	0	0	1.26
16	40	0	0	0	0.86	0	0	0.86
17	5.9	0	0	0	0	0.03	0	0.03
18	3.1	0	0.01	0	0.03	0	0	0.03
19	60	0	0	0	0.62	1.10	0	1.72
20	0.78	0	0.02	0	0	0	0	0.02
21	0.44	0	0.01	0	0	0	0	0.01
22	2.1	0	0.01	0	0	0	0	0.01
23	0.98	0	0.08	0	0	0	0	0.08
24	0.67	0	0.01	0	0	0	0	0.01
25	0.69	0	0.31	0	0	0	0	0.31
26	8.3	0	0	0	0.08	0.20	0	0.27
27	0.41	0	0	0	0	0.09	0	0.09
28	< 0.3	0	0	0.20	0	0.93	0	1.13
29	< 0.3	0	0	0	0	0.32	0.09	0.41
30	< 0.3	0	0	0	0	0.07	0.08	0.15
31	5.4	0	0	0.48	0	0	0	0.48
32	0.5	0	0	0.44	0	0	0	0.44

4.0 WASTE DISPOSAL EXPERIENCE FROM THE HUD DEMO

In Birmingham, Denver, and Seattle/Tacoma, the HUD contractor was required to conduct the EP-TOX test on abatement waste, and treat as hazardous any waste failing the test. Requirements in other states may vary since the RCRA program is delegated to States to administer. Accordingly, individual States may interpret the regulations somewhat differently in certain situations or have their own state regulations regarding specific wastes. Further, municipal regulations may impose additional requirements. The contractor reports the following summary experience of volumes of hazardous waste generated and associated disposal costs (The HUD Lead-Based Paint Abatement Demonstration (FHA), HUD, Office of Policy Development and Research (August 1991)):

TABLE VI: VOLUME OF HAZARDOUS WASTE AND DISPOSAL COSTS FOR THREE CITIES IN THE HUD DEMO

CITY/(# UNITS)	QUANTITY OF HAZ WASTE (lbs)		COST OF DISPOSAL		
	TOTAL	PER UNIT	TOTAL	PER UNIT	PER LB
Birmingham (23)	11,900	517	$10,221	$444	$0.86
Denver (57)	7,350	129	$9,625	$169	$1.31
Sea/Tac (16)	1,550	97	$4,675	$292	$3.02
3 CITIES (96)	20,800	217	$24,521	$255	$1.18

Thus, the per-unit average in the 3 cities was 217 lbs of hazardous waste, with an average disposal cost of $255 per unit. Disposal cost averaged $1.18 per lb. These costs include waste stream analysis by the disposal contractor, pick-up, and disposal but do not include TCLP testing costs incurred by the abatement contractor to classify waste, or the cost of abatement contractor management time devoted to the hazardous waste issue. More detailed cost breakdowns, e.g., transportation costs, were not available. The hazardous waste disposal costs experienced in the Demo are higher than independent estimates developed by EPA's Office of Solid Waste (OSW). For off-site immobilization followed by disposal (the most likely disposal method for waste from lead-based paint abatements), OSW estimates a cost of between $0.18 and $1.03 per pound. This is lower than the average cost of $1.18 experienced in the Demo, especially when we note that the Demo waste was not treated. The likely reason for the difference is the small volume of waste disposed of in the Demo. As Table VI shows, the per-pound disposal costs in the Demo were inversely related to the volume of waste disposed of.

Caution should be exercised in extrapolating the experience of the Demo to larger abatement programs. First, it must be remembered that solids and plastic sheeting were generally treated as ordinary solid waste in the Demo. A requirement to treat these items as subject to RCRA requirements could substantially increase the cost of disposal. However, no estimates are available to quantify this. Second, the mix of abatement strategies used in the Demo is unlikely to reflect future practice. For example, a considerable amount of paint stripping was conducted in the Demo to test out different approaches. In practice, however, paint removal is unlikely, except in special circumstances such as historic properties, because it is extremely labor-intensive. Thus, future abatements will probably generate much less sludge from stripping and heat gun operations than did the Demo. This factor would tend to reduce hazardous waste disposal costs as compared to the Demo.

5.0 CONCLUSIONS

The major conclusions of this study are as follows:

1. Waste from lead-based paint abatements in the categories: filtered wash-water, disposable work clothes and respirator filters, and rugs and carpets, is non-hazardous under RCRA, and may be disposed of as solid waste.

2. Waste in the categories: paint chips; HEPA vacuum debris, dust from air filters, and paint dust; sludge from stripping; unfiltered liquid waste; and, rags, sponges, mops, HEPA filters, air monitoring cartridges, scrapers, and other materials used for testing, abatement, and cleanup, may be either hazardous or non-hazardous, depending on abatement conditions. Waste in these categories may either be tested to determine whether it is hazardous, or may be disposed of as hazardous waste without testing. Since relatively small volumes of waste are expected in these categories, disposal as hazardous waste may be the cost-effective solution for the generator, depending on the cost of hazardous waste disposal, the volume of waste involved, the cost of TCLP testing, and the estimated probability that the waste will fail the TCLP test anyway.

3. Waste in the "solids" category, i.e., old woodwork, plaster, doors, and similar bulky components removed during abatement, was found to be generally hazardous when the lead level in the paint exceeded 4 milligrams per square centimeter, as determined by a laboratory analysis. This suggests that waste with paint at lower lead levels may be disposed of as solid waste. However, this study examined only a limited number of solid debris

samples selected in a non-random fashion. Thus, the results are suggestive only, and require confirmation in a larger study before being used as the basis for EPA policy with respect to waste from lead paint abatements.

4. Field X-Ray Fluorescence (XRF) measurements of lead in paint are not sufficiently accurate to permit an accurate determination of the hazardous waste status of "solids".

5. Waste in the category of plastic sheeting and tape used to cover floors and other surfaces during abatement is hazardous when the "Heat Gun" method of paint removal is used. However, this conclusion is based on a set of samples all taken from a single dwelling. When "Chemical Removal", "Abrasive Removal", or "Remove/Replace" are used, plastic sheeting is not hazardous. When "Encapsulation" or "Enclosure" are the abatement methods used, plastic sheeting sometimes slightly exceeds the TCLP limit for lead in waste.

6. The total quantity of lead abated in a room by each abatement method used has potential as a predictor of the hazardousness of plastic sheeting waste. More research would be needed to develop a predictive model, however.

7. In the HUD Demo, the cost of waste stream analysis, pick-up, and disposal of hazardous waste was $255 per unit. This does not include TCLP testing costs incurred by the abatement contractor to classify waste, or the cost of abatement contractor management time devoted to the hazardous waste issue. For this reason and because solids and plastic sheeting were not treated as hazardous waste in the Demo, hazardous waste disposal costs may be higher in practice. Further data is needed to quantify this.

APPENDIX A

EP-TOX TESTING DATA FROM THE HUD DEMO, SORTED BY WASTE CATEGORY AND LEAD CONCENTRATION IN THE EXTRACT

SAMPLE ID	SAMPLE DESCRIPTION	LEAD (ppm)	CAT	CITY	LOC
89-5010:	Paint from bathroom tile and master	0	1	1	1
89-5024:	Paint from baseboard trim	1.3	1	1	3
89-5023:	Heat gun paint debris	1.4	1	1	2
89-5019:	Debris from use of heat gun	2.4	1	1	2
89-5017:	Paint debris - "Peel-Away"	5.6	1	1	3
89-5005:	Paint debris - "Peel-Away"	5.8	1	1	1
89-5004:	Paint debris - heat gun	9.7	1	1	1
KTA - 5:	Paint chips	11.4	1	4	14
89-5015:	Paint from cedar shake	18	1	1	1
89-5133:	Paint chips	18	1	2	5
89-5161:	Exterior heat gun chips (paint)	52	1	3	6
89-5029:	HEPA vac debris	0	2	1	2
89-5016:	HEPA vac debris	1.3	2	1	3
89-5020:	HEPA vac debris	2.6	2	1	3
89-5026:	Negative air prefilter impregnated dust	7.5	2	1	3
89-5135:	HEPA vacuum contents	13	2	2	5
89-5127:	HEPA vacuum contents	22	2	2	4
KTA - 1:	Drywall with 4 sq.in 1.5 mg/sq.cm paint	0.5	3	4	14
KTA - 3:	Painted wood	0.7	3	4	14
90-146:	Window, attic vent, door frame	0.72	3	5	9
KTA - 4:	KTA#2, plus 4 sq.in 1.5 mg/sq.cm paint	1.7	3	4	14
KTA - 2:	Painted wood	2.1	3	4	14
90-147:	Window frame and trim	8	3	5	10
90-145:	Cedar shake, wall 1, 2nd level	140	3	1	1
89-5301:	Plastic from floor and bags	34	4	3	6
90-157:	Chemical treatment sludge	0.64	6	5	13
89-5163:	"Peel-Away" sludge w/rag dye, paper	1	6	4	7
90-154:	Chemical treatment sludge	1.22	6	5	12
90-150:	Heat gun sludge	12	6	5	10
90-153:	Heat gun sludge	40	6	5	11
89-5160:	Vinegar/chem neutralizer Peel-Away wash	620	6	3	6
89-5168:	Wash used before neutralizer (Peel-Away)	5.7	7	4	7
89-5030:	TSP wash water	45	7	1	3
89-5167:	TSP and neutralizer wash (Peel-Away)	50	7	4	7
89-5006:	Liq on poly below chem stripper cleanup	69	7	1	1
89-5003:	Non-filtered wash/rinse water	77	7	1	1
89-5169:	5 mic filt rinse water-sanding/Peel-Away	0	8	3	8
89-5165:	5 mic filtered rinse water - "Peel-Away"	0	8	4	7
89-5008:	20, 5 micron filtered hand wash water	0	8	1	2
89-5012:	5 micron filtered hand wash water	0	8	1	3
89-5166:	5 mic filtered rinse water - heat gun	0	8	4	7
89-5011:	Non-filtered hand wash water	0	8	1	2
89-5136:	Filtered (5 micron) waste water	0	8	2	5
89-5129:	Rinse/wash water supernatant	0	8	2	4
89-5132:	Rinse/wash water sludge	0.7	8	2	4
89-5159:	5 mic filtered rinse water - "Peel-Away"	4	8	3	6

SAMPLE ID	SAMPLE DESCRIPTION	LEAD (ppm)	CAT	CITY	LOC
89-5013:	5 micron filter used during hand washing	0	9	1	3
89-5018:	Sand paper from use of HERA sander	0	9	1	3
89-5137:	5 micron filter with waste	0.5	9	2	5
89-5164:	5 mic rinse water filter - "Peel-Away"	0.7	9	4	7
89-5162:	5 mic rinse water filter - "Peel-Away"	1.4	9	3	6
89-5027:	Negative air filter	4.7	9	1	2
89-5134:	HEPA cartridge	27	9	2	5
89-5131:	HEPA filters from vacuum	95	9	2	4
89-5138:	Wiping of HEPA vac filter	97	9	2	5
89-5007:	Paper towels - chem stripper cleanup	110	9	1	1
89-5302:	Rag - TYVEK suit used to wipe floor	220	9	3	6
90-152:	TYVEK suit and rubber gloves - heat gun	0	10	5	11
89-5172:	PAPR filter - Peel Away	0	10	4	7
90-155:	Respirator filter - chemical treatment	0	10	5	12
90-149:	TYVEK suit and rubber gloves - heat gun	0	10	5	10
89-5014:	Respirator filters - heat gun use	0	10	1	1
89-5021:	Protective suit - chem stripper use	0	10	1	3
89-5022:	Respirator filters (3 weeks use)	0	10	1	3
90-156:	TYVEK suit and rubber gloves-chem treat	0.53	10	5	12
90-148:	Heat gun - respirator filter	0.54	10	5	10
90-151:	Heat gun - respirator filter	0.55	10	5	11
90-158:	Respirator filter - chemical treatment	0.68	10	5	13
89-5170:	PAPR filter - mainly sanding	0.9	10	3	8
90-159:	TYVEK suit and gloves	0.99	10	5	13
89-5009:	TYVEK suit used during heat gun use	1.2	10	1	1
89-5128:	Respirator filters	2.1	10	2	4
89-5130:	Composite poly & TYVEK suits	3.2	10	2	4
89-5171:	PAPR filter - mainly heat gun use	3.9	10	4	7
89-5300:	Rug and pad	0	11	3	6
89-5032:	Orange foam back and fiber back carpet	0	11	1	1
89-5031:	Red & black foam back carpet	0	11	1	1
89-5025:	Red carpet	0	11	1	2
89-5033:	Corrugated foam pad; fiber back carpet	0	11	1	1
89-5028:	Green carpet	1.4	11	1	2
89-5139:	Blank of wipe "Diaparene"	0	12	2	5

LOCATION CODES

1 = 4033 Vallejo (Denver)
2 = 4320 Zuni (Denver)
3 = 2921 Curtis (Denver)
4 = 615 Udel (Indianapolis)
5 = 922 E. 42nd Street (Indianapolis)
6 = 905 Drum (Washington, D.C.)

7 = 6155 Parkway (Baltimore)
8 = 5716 Sheridan (Washington, D.C.)
9 = 3425 38th Place (Birmingham)
10 = 1778 Jefferson (Birmingham)
11 = 4104 Main Street (Birmingham)
12 = 1415 30th Street (Birmingham)
13 = 4340 Greenwood (Birmingham)
14 = KTA samples - Baltimore, address unknown

CITY CODES

1 = Denver
2 = Indianapolis
3 = Washington, D.C.
4 = Baltimore
5 = Birmingham, Alabama

CATEGORY CODES

1 = Paint chips
2 = HEPA vac debris, dust from air filters, paint dust
3 = Old woodwork, plaster, windows, doors, and similar bulky components removed from the building
4 = Plastic sheets and tape used to cover floors and other surfaces during LBP removal
5 = Solvents and caustics used during stripping
6 = Sludge from stripping
7 = Unfiltered liquid waste such as wash-water from general cleanup or from decontaminating surfaces after solvents have been used; unfiltered liquid waste from exterior blasting
8 = Filtered wash water
9 = Rags, sponges, mops, HEPA filters, air monitoring cartridges, scrapers, and other materials used for testing, abatement and cleanup
10 = Disposable work clothes and respirator filters
11 = Rugs and carpets
12 = Blanks

APPENDIX B

SOLIDS SAMPLES FROM THE HUD DEMO ANALYZED BY TCLP

Sample ID	Unit Address	Substrate	Location	XRF (mg/cm^2)
101	5230 16th	WTM	Garage WL4	6.1
102	17 Tacoma	BSB	BD # 2	N/A
103	3924 E. 30th	DRF	EXT (LV RM)	3.7
104	3421 N. Gale	FENCE	EXT	N/A
105	2739 Mura	DOOR	EXT	5.9
106	1321 E. 27th	WDW	BSM	8.7
107	2931 Riggs	DOOR	GAME # 2	2.8
108	1422 E. 34th	DRF	KIT	3.1
109	1422 E. 34th	WSL	EXT	8.0
110	1422 E. 34th	WDW	EXT	8.2
111	1422 E. 34th	DRF	BAT	5.3
112	1422 E. 34th	COL	EXT	9.7
113	1422 E. 34th	DOR	EXT	6.8
114	1422 E. 34th	WTM	EXT	4.6
115	3449 Kinnear	DOR(FRONT)	EXT	3.1
116	3449 Kinnear	DOR(FRONT)	EXT	4.8
117	3449 Kinnear	DOR WLA	EXT	3.1
118	3449 Kinnear	DRF WLA	EXT	4.8
119	1649 Temple	DRF(FRONT)	EXT	9.4
120	1649 Temple	DRF (REAR)	EXT	9.4

APPENDIX C

PLASTIC SAMPLES FROM THE HUD DEMO

ID	ADDRESS	SEL	ROOM	MEAN (mg/cm^2)	N	METHOD
9	4895 Vallejo	ORG	KIT	9.6	1	Abrasive Removal
8	4895 Vallejo	ORG	LVG ROOM	9.4	1	Abrasive Removal
7	4895 Vallejo	ORG	HALL (BLV)	5.4	2	Abrasive Removal
20	1304 Walters	ORG	BED 2	1.3	2	Chemical Removal
21	1304 Walters	ORG	BED 1	1.4	2	Chemical Removal
25	1304 Walters	ORG	BASEMENT	2.8	2	Chemical Removal
24	1304 Walters	ORG	BATH (2LV)	1.8	2	Chemical Removal
22	1304 Walters	ORG	KIT	1.5	2	Chemical Removal
23	1304 Walters	ORG	LVG ROOM	1.6	2	Chemical Removal
5	1665 Macon	ORG	LVG ROOM	3.4	5	Encap, Enclose
6	2516 N. 8th	ORG	BATH	8.6	8	Encap, Enclose
4	1308 Wallace	ORG	BATH	9.4	13	Encapsulation
3	1308 Wallace	ORG	KIT	5.6	16	Encapsulation
29	1422 East 34th	ORG	PANTRY	2.8	7	Enclosure, R/R
30	1422 East 34th	ORG	BATH	3.6	2	Enclosure, R/R
16	2931 Riggs	ORG	HALL (LVL 2)	9.3	2	Heat Gun
11	2931 Riggs	ORG	DIN RM 1	6.9	2	Heat Gun
14	2931 Riggs	ORG	BED 3	8.8	2	Heat Gun
15	2931 Riggs	ORG	LVG ROOM	8.9	8	Heat Gun
13	2931 Riggs	ORG	BED 1	8.7	5	Heat Gun
2	1308 Wallace	SUB	GAME	3.2	1	Encapsulation
32	3745 Eudora	SUB	EXT WALL	1.2	10	Encapsulation
1	1665 Macon	SUB	HALL	2.6	2	Encapsulation
31	338 Chester	SUB	BED 2	2.1	12	Encapsulation
26	2931 Riggs	SUB	KIT	1.3	5	Enclose, Heat Gun
27	4895 Vallejo	SUB	HALL (LV1)	2.2	1	Enclosure
28	3565 Krameria	SUB	KIT	7	2	Enclosure, Encap
10	2931 Riggs	SUB	LAUNDRY	2.6	2	Heat Gun
12	2931 Riggs	SUB	BED 2	7.4	2	Heat Gun
18	2931 Riggs	SUB	DIN RM 2	1.1	2	Heat Gun, Chem
17	2931 Riggs	SUB	GAME #1	0.4	1	Heat Gun, Chem
19	2931 Riggs	SUB	BATH	8.3	10	Heat Gun, Enclose
N/A	3311 West Walsh	N/A	BED 3	6.1	1	Chemical Removal
N/A	617 Elk	N/A	PANTRY	5.6	8	Encap, Enclose
N/A	1321 East 27th	N/A	BATH	16	7	Encapsulation
N/A	1321 East 27th	N/A	KIT	11.3	6	Encapsulation
N/A	407 South 30th	N/A	BATH (LVL 1)	9.9	6	Enclosure
N/A	407 South 30th	N/A	HALL (1LV)	4.1	8	Enclosure, R/R
N/A	407 South 30th	N/A	KIT (LVL 1)	4.7	4	Enclosure, R/R
N/A	407 South 30th	N/A	LAUNDRY (BLV	4.5	1	Remove/Replace
N/A	3311 West Walsh	N/A	HALL (BLV)	7.5	4	Remove/Replace
N/A	1422 East 34th	N/A	KIT	4	8	R/R, Encl

CODES: MEAN = Arithmetic average of XRF measurements in the room
N = Number of XRF measurements in the room
SEL = Selection code
ORG = original sample actually obtained
SUB = HUD substitution
N/A = originally requested sample which was unavailable

APPENDIX D

REGRESSION ANALYSIS FOR PLASTIC SAMPLES

Several regression analyses were conducted to further explore and quantify the relationship between the mass of lead abated and the TCLP results for plastic samples. The first analysis had TCLP as dependent variable, and estimates of the total mass of lead abated by each abatement method (see Section 3.4) as independent variables. The fitted model was

TCLP (mg/l) = 0.23 + 0.65*[ABR REM] + 2.40*[CHEM REM]
+ 0.64*[ENCAP] + 40.96*[HEAT GUN]
+ 13.56*[ENCL] - 31.83*[REM/REP],

where each dependent variable represents the total kilograms of lead abated in a room by the corresponding abatement method. This model explained 85.1% of the variability in the TCLP results. However, only the variables HEAT GUN and ENCL were significant in the model. Accordingly, a second regression, with only these two variables as independent variables, was run, resulting in the following fit:

TCLP (mg/l) = 0.33 + 40.9*[HEAT GUN] + 13.3*[ENCL].

This model explained 84.8% of the variability in TCLP, so there was essentially no loss of explanatory power versus the full model. Finally, a model with just HEAT GUN as independent variable was run, with the following result:

TCLP (mg/l) = 1.79 + 41.4* [HEAT GUN].

This model explained 78.4% of variability.

The second and third models have potential use in developing decision rules for determining whether plastic sheeting from an abatement needs to be treated as hazardous waste. For example, the second model predicts that 10 of the 32 samples would fail the TCLP test. Of these 10, 8 actually did. Thus, 4 of the 12 samples actually failing the TCLP test are <u>not</u> predicted to do so by the model, while 2 samples which did <u>not</u> fail are predicted to fail. The 4 samples not predicted to fail by the model are those with the 4 smallest TCLP levels above the 5 mg/l cutoff. The 2 samples incorrectly predicted to fail both had TCLP levels below the detection limit of 0.3 mg/l. The predicted values from the model were 11.2 and 12.7 mg/l respectively. The predictive power of this model, based on currently available data, is clearly limited. Further data collection and model refinement would be necessary before practical application.

The third model predicts 7 failures of the 12 that actually occurred. It fails to predict correctly for the 5 samples with the smallest TCLP levels exceeding 5 mg/l. However, the model always predicts correctly for those samples whose TCLP level was less than 5 mg/l. This simpler model performs slightly better than the two-variable model. Both the one- and two-variable models have potential use as predictive tools, given extensive further testing and refinement.