IDENTIFICATION OF DANGEROUS LEVELS OF LEAD IN PAINT, DUST, AND SOIL

TITLE IV OF TSCA SECTION 403

AN ECONOMIC ANALYSIS

DRAFT: January 10, 1994

Abt Associates Inc.

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EXECUTIVE SUMMARY

ES.1 BACKGROUND

On October 28, 1992, Congress enacted the Housing and Community Development Act of 1992. Title X of that Act -- the Residential Lead-Based Paint Hazard Reduction Act of 1992 -- included among other things an amendment adding "Title IV - Lead Exposure Reduction" to the Toxic Substances Control Act (TSCA). Among the various requirements of TSCA Title IV are those set forth under *Section 403 - Identification of Dangerous Levels of Lead.* Section 403 reads as follows:

> "Within 18 months after the enactment of this title, the Administrator shall promulgate regulations which shall identify, for purposes of this title and the Residential Lead-Based Paint Hazard Reduction Act of 1992, lead-based paint hazards, lead-contaminated dust, and lead-contaminated soil."

ES.2 AGENCY APPROACH TO SECTION 403 REQUIREMENTS

The Agency's approach to the TSCA Section 403 requirements is to establish quantitative standards for lead in residential soil and dust, and a qualitative standard for lead in paint. That is, for soil and dust, EPA will identify specific, measurable levels of lead in these media as the hazard levels. For lead paint, the Agency has determined that the condition and location (accessibility) of the surfaces bearing the lead paint are more indicative of the potential for a hazard to be present than are measurements of the amount of lead present on those painted surfaces. Consequently, the lead paint hazard will emphasize those characteristics rather than a quantifiable level of lead on painted surfaces.

The Agency recognizes that, from a public health perspective, human exposure to lead at any level is undesirable. However, the Agency also recognizes that the costs to society and individuals to reduce lead exposure from paint, soil and dust can be substantial. Therefore, from an overall public welfare perspective,. it is important to balance properly the public health benefits achieved from reducing exposure to lead with the costs that are incurred by society to achieve those benefits.

The Agency also recognizes that while the incidence and severity of adverse effects of lead generally operate along a continuum of exposure levels, there are different degrees of potential human health hazards that suggest different forms of remedies to reduce or prevent exposure. The analysis in the current report illustrates the significant contribution to social welfare that could be made by fitting a remedial response to the particular hazards of a home. The Agency will also suggest the types of responses believed to be appropriate for hazards of different magnitudes and for different sources (namely, soil, dust, and/or paint). It is the Agency's intent that by helping to set priorities in addressing exposure sources, it will aid in maximizing lead exposure reductions within constraints imposed by practical resource limitations.

With respect to paint, the Agency recognizes that a dominant pathway of exposure is through the contamination of dust and soil. Consequently, efforts undertaken to reduce exposure to lead in dust and soil can effectively reduce a substantial portion of exposure due to lead in paint, even without specific lead paint abatement efforts. However, in those cases where the lead paint surfaces are in a deteriorating condition, there is an increased potential for both direct ingestion from accessible surfaces, and an increased potential for continual recontamination of dust and soil even with dust and/or soil abatement. As a result, the Agency has elected to focus its paint hazard standard on the condition and location of the areas having lead paint.

ES.3 PURPOSE OF THE ANALYSIS

The goal of the economic analysis presented here is to help inform the decisions regarding the specific choices of hazard levels to be identified under Section 403. This report uses benefit-cost analysis to gain insights into possible hazard levels based upon the amount of lead in paint, soil, and dust and upon the condition and location of lead-based paint. The results of these benefit-cost analyses identify optimal lead hazard levels that maximize the net benefits of undertaking lead exposure reduction actions.

ES.4 SYNOPSIS OF THE BENEFIT-COST APPROACH

ES.4.1 General Overview

Benefit-cost analyses provide an orderly framework both for evaluating the impacts of a specific hazard level and abatement strategy, and for comparing the relative merits of alternative levels and strategies. A complicating aspect of evaluating the impacts of the Section 403 regulations, both in terms of their costs and benefits, is that these standards do not specifically require that any exposure reduction activities be undertaken as a result of their promulgation. That is, these standards do not themselves compel any public or private entity to comply with the levels set. However, the Agency recognizes that these hazard levels will be used widely by federal, state, local and private entities to guide on-going and future efforts to manage the hazards of lead in paint, soil and dust. Therefore, the Agency considers it appropriate to attribute changes in the nature or extent of abatement to this rule. By following this approach, the Agency can arrive at a set of standards which, when acted upon by public and private entities, will maximize net social welfare.

Because the Section 403 rules do not mandate specific actions, it is not possible to analyze fully developed regulatory alternatives per se. Instead, an approach has been taken that considers what the benefits and costs would be if some broadly defined abatement efforts are undertaken for reducing lead in these media. These abatement alternatives attempt to capture the range of some reasonable extremes of full-scale lead abatement actions and exposure reduction efforts conducted on a more limited scale.

In carrying out these analyses, a baseline estimate was first made of the magnitude and value of the health damages that would be incurred by several generations of children assuming that future exposure levels to lead in paint, soil, and dust are not changed from current conditions. Against this baseline, analyses were performed of the residual damages that would be incurred if lead levels in paint, soil and dust were reduced to lower levels as a result of the broadly defined abatement activities noted above, reflecting assumptions made about their efficacy. The benefits of these activities were then determined from the difference between the estimated baseline damages and the residual, post-abatement damages. These estimated benefits were then compared with the estimated costs of carrying out the various abatement activities, identifying the hazard levels generating health benefits greater than costs and, in particular, the hazard levels maximizing the net benefits to society.

ES.4.2 Abatement Decision Rules

This analysis considers five different decision rules under which homeowners initiate abatement. It is assumed that this abatement is prompted by and takes place just prior to the birth of a child, in order to avoid subsequent exposures for the newborn. These decision rules vary in the degree to which EPA's guidance, primarily in the form of hazard levels, induces the abatements. At one extreme is a decision rule in which EPA provides no hazard levels. Instead, households are assumed to obtain perfect information about the benefits and costs of varioius abatement options for their respective homes and to undertake the one, if any, with the highest net benefits. The decision rule is called voluntary optimum. It has the highest net benefits of all decision rules considered.

This decision rule also serves as a benchmark against which the other four decision rules can be judged, both in terms of net benefits achievable and the nature of the information households have. Of course, a primary role of promulgating hazard levels is to provide households with information that will induce abatements where appropriate. This objective is complicated by the fact that there is a tradeoff between conciseness in the way hazard levels are promulgated and the appropriateness of any set of hazard levels for a particular home. Conciseness may be an objective in the design of hazard levels to be promulgated because it is likely that the more concise the hazard levels are, the more accessible the hazard information is for homeowners. If, for example, EPA promulgates a hazard level of 2,300 ppm for soil, a homeowner with a soil reading above this level could take the hazard level as unambiguous guidance to abate soil. However, it may not be appropriate for all homeowners with soil readings greater than 2,300 ppm to initiate soil abatement.

This tradeoff is considered in the other four decision rules evaluated in the benefit-cost analysis. These decision rules vary in the extent to which recommendations are made for the three different media - soil, dust, and paint - and therefore in the extent to which homeowners may be induced to take action. Under some decision rules, a recommendation is made for only one medium, such as dust, and under other decision rules, recommendations are made for all three media. Yet, the hazard levels considered are all very simple. The recommendations considered are ones which can be expressed as one set of numbers, such as one hazard level for soil for all houses in the country. While concise, such recommendations cannot avoid introducing some errors in abatement choices since the recommendations are never exactly tailored to any particular house's circumstances.

Under all four decision rules, a recommendation is made to homeowners to conduct abatement if lead-based paint is in bad condition. Under the first decision rule, this is the only explicit recommendation made. Under the second decision rule, a recommendation is also made to abate if lead exceeds a threshold in one particular medium. Each medium is considered in turn, so that there are three examples under this decision rule - what happens if a hazard level for soil alone is promulgated, what happens if a hazard level for dust alone is promulgated, and what happens if a hazard level for paint alone (based upon the amount of lead present in addition to condition) is promulgated. The third decision rule examines the net benefits from promulgating hazard levels for two media in tandem rather one medium alone. All combinations (soil/dust, soil/paint, and dust/paint) are evaluated. The fourth decision rule evaluates the net benefits of promulgating all three hazard levels (soil, dust, and paint) together as well as the paint condition recommendation.

For any given medium under a decision rule, a wide range of levels were evaluated in the benefit-cost analysis. When more than one medium is combined as a set of candidate hazard levels, such as soil and dust hazard levels under the two-media decision rule, the number of potential combinations is enormous. All soil levels from 100 ppm to 3,000 ppm are combined as candidate hazard levels with all dust levels from 100 ppm to 2,000 ppm. However, this analysis focuses primarily on the set of hazard levels that have the highest net benefits. The best set for each decision rule is compared with the best sets for all other decision rules. In this way, it is possible to identify the best combination of media for which hazard levels could be promulgated and the best values those hazard levels should take.

ES.4.3 Costs

The cost analysis considered both testing and abatement costs for all three media. Unit cost estimates were developed first and then applied to the relevant population in each decision rule to arrive at total costs. Each activity is discussed separately below.

Unit Costs

Testing

The unit testing costs for each media depend on the number of samples taken, the sampling method and the cost of analysis. Using the Agency draft testing standards as a guide for the number of samples, the estimated unit testing costs are $230 for interior paint, $115 for exterior paint, $138 for soil and $230 for dust.

Abatement

Abatement unit costs depend primarily on the activities involved. Ten specific abatements choices were considered. These include two dust abatements (recurrent and nonrecurrent); two soil abatements (high-end and low-end soil abatements); two paint abatements (high-end and low-end paint abatements) and four combined paint and soil abatements (high-end paint with high-end soil; high-end paint with low-end soil; low-end paint with high-end soil; and low-end paint with low-end soil). The components of each abatement scenario are shown in Exhibit ES-1.

EXHIBIT ES-1

Summary of Abatement Scenarios

Abatement Scenario	Activities
Nonrecurrent Dust	Families moved off-site, hard surfaces (floors, woodwork, window wells and some furniture) vacuumed with a high-efficiency particle accumulator (HEPA) vacuum. Hard surfaces also wiped with a wet cloth (an oil treated rag was used on furniture) following vacuuming.
Recurrent Dust	Every ten years a thorough cleaning as listed under nonrecurrent dust. Every month an additional standard house cleaning consisting of general dusting, vacuuming. cleaning bathrooms and wiping window sills.
High-end Paint	Full abatement of windows, doors, woodwork and walls by removal or replacement and a high-end dust abatement.
Low-end Paint	Replacement of windows and high-end dust abatement.
High-end Soil	Removal of six inches of top soil, installation of a barrier and replacement of soil with new soil tested under 150 ppm lead, resodding and high-end dust abatement.
Low-end Soil	Resodding including grading but no removal of existing grass plus high-end dust abatement.
High-end Soil and High-end Paint	Combination of high-end soil abatement and high-end paint abatement.
High-end Soil and Low-end Paint	Combination of high-end soil and low-end paint abatement.
Low-end Soil and High-end Paint	Combination of low-end soil and high-end paint abatement.
Low-end Soil and Low-end Paint	Combination of low-end soil and low-end paint abatement.

Two types of dust abatement were modeled. Nonrecurrent dust abatement assumes a one-time high-end cleaning during which the occupants are moved off-site; hard surfaces are vacuumed with a high efficiency particle accumulator vacuum and wiped with a wet rag (or an oil treated rag in the case of furniture). Based upon available information, the cost was estimated to be $750. In addition to being considered as a separate abatement, the high-end dust abatement was included as a component of both the paint and soil abatements as noted below. The second form of dust abatement involved an initial high-end dust abatement, as described above, followed by monthly routine house cleaning with additional high-end abatements every ten years. This recurrent dust abatement scenario reduces the dust level to 100 parts per million (ppm). The cost of the routine house cleaning was estimated to be $38 per month, repeated monthly. The present value of recurrent dust abatement, calculated over the fifty year lifetime of the model, is $7,676.

For paint abatement, the high-end level of abatement assumed full abatement of windows, doors, woodwork and walls, as well as high-end level dust abatement (see above). The present value cost of the high-end paint abatement was estimated to be $10,500 per home. It is assumed to be permanent and to render the home free of lead-based paint. The surrogate used to model low-end paint abatement was replacing only windows, and consequently was applicable only to those homes having windows with lead-based paint present. As with the high-end abatement, the cost of one-time high-end dust abatement was also included. The unit cost (i.e., cost per home) was estimated to be $2,750, and the abatement was assumed to be permanent for the windows. The effectiveness was assumed to be equivalent to reducing the dust lead level by 8.6%, the portion windows contribute to total lead-based paint area in the 1989-90 Housing and Urban Development Department (HUD) survey results.

The high-end soil abatement was assumed to involve removing the top six inches of soil, filling the yard with new soil having a lead level below 150 ppm, and resodding. High-end dust abatement in these homes was also included. Soil with a lead level above 2000 ppm was assumed to be treated as hazardous waste; thus, hazardous waste transportation and disposal costs were added. In addition, if the house had exterior lead-based paint, the cost of its removal was included because this abatement was needed to ensure the effectiveness postulated. The cost of the high-end soil abatement was estimated to be $7,998 if the soil was not considered a hazardous waste and if there was no lead in the exterior paint. Waste disposal added $8,414 and exterior paint abatement added $5,000 to the abatement cost. The high-end soil abatement was assumed to be permanent. The low-end soil abatement scenario assumed resodding with some preparatory work on the ground and was estimated to cost $2,860. It was assumed that the low-end soil abatement results in a post-abatement soil level equivalent to 500 ppm. The low end soil abatement was assumed to require repeated resodding every five years for a net present value unit cost of $7,493.

Total Costs

The total costs are shown in Exhibit ES-2 for the five decision rules evaluated. Each total cost has a testing and an abatement component. The total testing costs depend on the decision rule and the number of media tested. Testing takes place at the birth of the first child and total discounted testing costs over the fifty year span of the model range from $14.9 billion for two media to $24.3 billion for all three. The abatement costs range from $13.9 billion for

EXHIBIT ES-2
Total Costs for Five Alternative Decision Rules

	Decision Rules[a]		Soil (ppm)	Dust (ppm)	Paint (XRF, mg/cm²)	Nonintact Paint Abatement Recommended	Abatement Costs ($ million)	Testing Costs ($ million)	Total Costs ($ million)	Costs by Type of Abatement Chosen[g] ($ million)									
										HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NRD
1.	Voluntary Optimum[b]		-	-	-	No	13,896	24,222	38,118		26		1,992						11,878
2.	Paint Condition Only[c]		-	-	-	Yes	24,668	14,982	39,650	20,134	3,517					943		74	
3.	Single Medium Plus Condition[d]	3a.	2,300	-	-	Yes	28,344	14,982	43,326	20,134	3,442		3,475			943		350	
		3b.	-	1,200	-	Yes	29,646	24,346	53,992	20,260	3,462	272	1,420	978		943	87	74	2,150
		3c.	-	-	20	Yes	25,013	14,982	39,995	20,429	3,567					943		74	
4.	2-Media Plus Condition[e]	4a.	2,300	1,200	-	Yes	31,903	24,346	56,249	20,260	3,387	272	3,475	978		943	87	350	2,150
		4b.	2,300	-	20	Yes	28,689	14,982	43,671	20,429	3,493		3,475			943		350	
		4c.	-	1,200	20	Yes	29,991	24,346	54,337	20,555	3,551	272	1,420	978		943	87	74	2,150
5.	3-Media Plus Condition[f]		2,300	1,200	20	Yes	32,248	24,346	56,594	20,555	3,438	272	3,475	978		943	87	350	2,150

[a] Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust and 20 mg/cm² in paint.

[b] Each home selects abatement (or no abatement) that has highest net benefits.

[c] Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of XRF level or net benefits. Home owners choose the paint abatement method that generates the highest net benefits. Results are reported only for homes that exceed recommended levels.

[d] Within the full range of individual soil, dust and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize the net benefits. Results are reported only for homes that exceed recommended levels.

[e] Within the full range of individual soil, dust and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize the net benefits. Results are reported only for homes that exceed recommended levels.

[f] Within the full range of individual soil, dust and paint hazard level combination that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize the net benefits. Results are reported only for homes that exceed recommended levels.

[g] Abatement Codes: High Paint(HP); Low Paint(LP); High Soil(HS); Low Soil(LS); Recurrent Dust (RD); High Paint and High Soil(HP/HS); High Paint and Low Soil(HP/LS); Low Paint and High Soil (LP/HS); Low Paint and Low Soil (LP/LS); Nonrecurrent Dust (NRD). The abatement activities were described in Exhibits 4.1-4.6.

the voluntary optimum to $32.2 billion for the three media plus paint condition constrained optimum. The higher value of the latter is a result of households being required to choose more expensive abatements to meet the constraining criteria than they would have chosen voluntarily. The majority of abatement costs of the constrained decision rules result from abating all nonintact paint. The total costs, including both testing and abatement, range from $38 billion to $56 billion.

ES.4.4 Benefits

The benefits associated with various combinations of hazard levels and abatement choices have been examined using the following three primary measures:

- Changes in the characteristics of the population blood-lead distributions for children;

- Estimates of avoided incidence of adverse health effects, specifically, avoided loss of IQ points, avoided incidence of IQ < 70, avoided incidence of PbB > 25 μg/dl, and avoided incidence of neonatal mortality; and

- Monetary value of the avoided adverse health effects noted above.

Exhibit ES-3 summarizes the benefits for ten decision rule options. Included there are the nine options that are described above in which the hazard levels for paint, soil and dust were derived primarily from net benefits considerations. For the tenth decision rule, hazard levels were obtained that would minimize an individual's risk of experiencing high blood-lead levels. The rule was designed to result in less than 10% risk of blood-lead exceeding 10 μg/dl, less than 5% risk of blood-lead exceeding 15 μg/dl, and less than 1% risk of blood-lead exceeding 20 μg/dl. Setting hazard levels of 500 ppm for soil and 400 ppm for dust (with paint in bad condition also inducing abatement) accomplishes the risk-based goal.

It is important to note that the benefits estimated here include only those that were quantifiable given currently available data. These types of benefits are comparable to those that have been estimated for children in conjunction with other recent regulations aimed at reducing environmental exposure to lead. However, other potential benefits exist for reducing childhood lead exposure, such as avoided impairment of certain metabolic processes and possible avoidance of cancer. In addition, benefits realized to the adult population from reduced exposure to lead in residential settings have not been included in the base analysis because available risk information is considered weak in the risk assessment community. These benefits are estimated, however, in the sensitivity analysis.

The largest benefits overall are estimated to derive from the 500/400/- decision rule, with approximately $67 billion in benefits over the full 50-year modeling time frame. This outcome was expected since the environmental exposure to lead is reduced more than under all the other decision rules resulting in the lowest post-abatement geometric mean blood-lead values (2.45 μg/dl), the lowest 90th percentile value (6.43 μg/dl) and the largest values for avoided incidence of IQ point loss, IQ < 70, PbB > 25 μg/dl and incidence of neonatal mortality.

Exhibit ES-3
Summary of Estimated Benefits

	Post-Abatement Population Blood Lead Distribution Characteristics (μg/dl)				Avoided IQ Point Loss		Avoided Incidence of:			Value of Benefits over Full Model Timeframe ($B)
	GM	GSD	Med.	90th %-tile	Total	Avg./Child.	IQ < 70	PbB > 25	Neonatal Mortality	
Baseline	4.06	2.45	3.91	13.30	0	0	0	0	0	$0.0
Decision Rule:										
Voluntary Optimum	2.52	2.70	2.40	9.47	1,912,011	1.34	5,434	63,422	0	$48.2
Paint Condition Only	3.82	2.47	3.72	12.55	319,818	0.86	1,081	14,744	48	$7.3
Single Media: 2300/-/-	3.78	2.43	3.71	11.99	490,626	1.16	1,909	30,736	48	$11.2
Single Media: -/1200/-	3.32	2.39	3.36	9.81	1,316,456	1.94	4,874	68,513	48	$32.9
Single Media: -/-/20	3.82	2.47	3.72	12.55	321,631	0.86	1,084	14,745	48	$7.4
2-Media: 2300/1200/-	3.30	2.35	3.36	9.67	1,402,677	1.98	5,305	77,479	48	$34.9
2-Media: 2300/-/20	3.78	2.43	3.71	11.99	492,439	1.15	1,912	30,376	48	$11.2
2-Media: -/1200/20	3.32	2.37	3.36	9.81	1,318,269	1.93	4,877	68,513	49	$33.0
3-Media: 2300/1200/20	3.30	2.35	3.36	9.67	1,404,490	1.97	5,308	77,479	49	$35.0
2-Media Option to Minimize High Blood Leads: 500/400/-	2.45	2.2	2.56	6.43	2,751,452	1.58	8,823	94,656	75	$66.7

Note: Except for the monetary value of the benefits shown in the last column, benefits presented here are for first model year cohort.

The Voluntary Optimum rule elicits the largest benefits among those decision rules derived from net benefits considerations. The value of the benefits for the Voluntary Optimum rule over the full modeling time frame is $48.2 billion. Although the post-abatement geometric mean for the Voluntary Optimum at 2.52 μg/dl approaches the value estimated for the 500/400/- rule noted above, its geometric standard deviation (GSD) of 2.7 is significantly larger than the GSD of 2.2 for the 500/400/- rule. This difference in the spread of values translates into a higher 90th percentile value (9.47 μg/dl) for the Voluntary Optimum rule and a lower incidence of avoided blood lead values above 25 μg/dl. It is also noteworthy that the Voluntary Optimum rule results in no avoided cases of neonatal mortality, since this rule does not induce any high-end paint abatement (a necessary condition to obtain this benefit).

As noted in the preceding section, the nine decision rules arrived at using net benefits consideration include the constraint that lead-based paint in bad condition will induce paint abatement regardless of the XRF value. Listed as Paint Condition Only, Exhibit ES-3 shows that this component alone elicits $7.3 billion in benefits over the full modeling time frame.

Among the decision rules setting specific hazard levels arrived at using net benefits considerations, the largest benefits are seen for those which include dust at 1200 ppm among the hazard levels (i.e., -/1200/-, 2300/1200/-, -/1200/20, and 2300/1200/20). The total benefits for these four rules range from $33.0 to $34.9 billion, with comparable impacts on blood lead distributions, avoided loss of IQ points, avoided incidence of IQ < 70, avoided incidence of PbB > 25 μg/dl, and avoided neonatal mortality. Among these four decision rules, slightly higher benefits accrue for the two that also include soil at 2300 ppm.

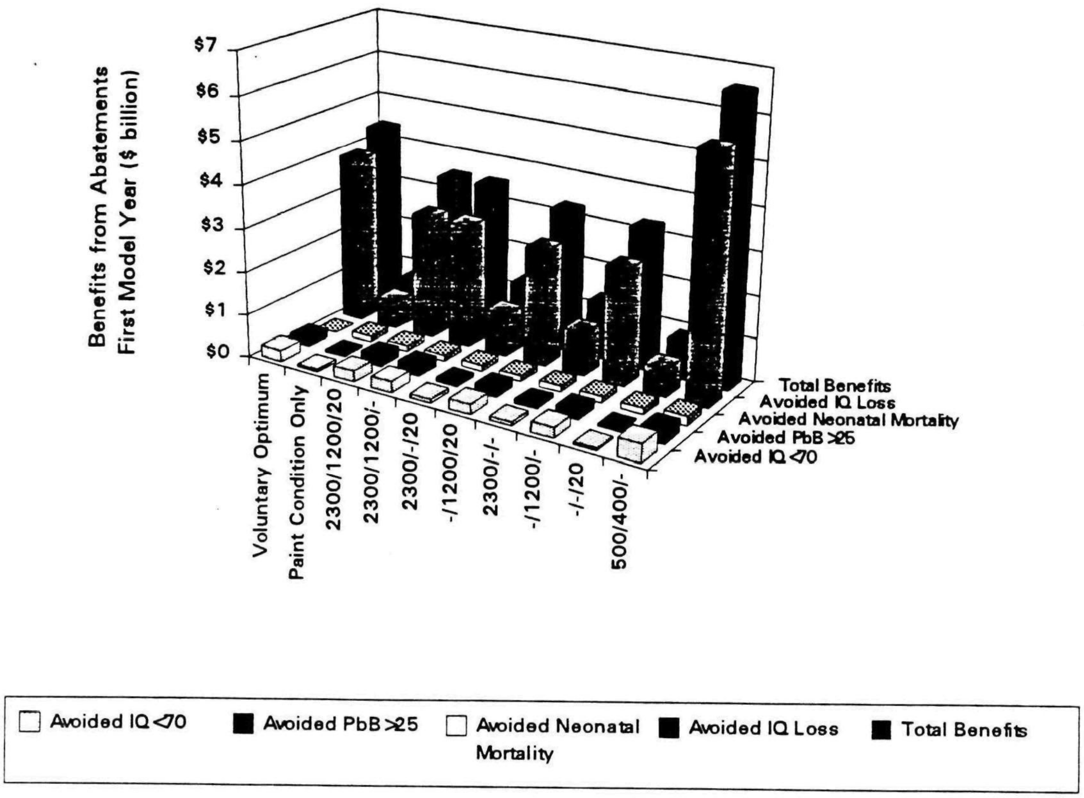
Of the three rules setting hazard levels that do not involve a dust component, the largest benefits are seen for the two involving soil at 2300 ppm (2300/-/- and 2300/-/20). These rules have total benefits estimated at $11.2 billion, with virtually identical results for the health effects avoided.

The lowest benefits among the rules setting specific hazard levels come from the single media rule setting paint at an XRF of 20 (-/-/20). The total benefits for this rule are estimated to be $7.4 billion. Note, however, that the paint condition component alone is estimated to provide $7.3 billion, indicating that setting the additional hazard level at an XRF of 20 for all paint regardless of condition provides little additional benefit above that resulting from abatement of paint in bad condition.

Exhibit ES-4 displays the relative contribution of the monetized value of each of the categories of benefits based on the first model year abatements for each decision rule. The relative contributions of the benefits categories are comparable for the entire modeling period.

By far, the major contribution to the value of the benefits derives from the avoided loss of IQ points. For all of the decision rules, this component of the benefits contributes between 75% and 90% of the value of the benefits. The contributions of the avoided incidence of IQ < 70 and of blood-lead levels > 25 μg/dl are comparable for each decision rule, generally contributing between 5% and 7% of the total benefits each.

Exhibit ES-4. Distribution of Monetized Benefits by Category for First Model Year Abatements.



The most variable contributor to the value of the benefits is avoided neonatal mortality. Except for the Voluntary Optimum and the 500/400/- decision rules, the monetized value of these benefits is comparable, approximately $140 million for the first year. For the Voluntary Optimum, neonatal mortality avoidance makes no contribution, while for the 500/400/- rule the value is about $220 million. Excluding the voluntary optimum, the avoided neonatal mortality benefits as a percentage of the total are highest for those decision rules with the lowest total benefits, and highest for those with the lowest benefits. For example, in the Paint Condition Only rule, the first year benefits are estimated to be about $890 million, and the neonatal mortality benefit at $138 million comprises about 16% of the total. By contrast, the 2300/1200/20 rule has total first year benefits of $3.5 billion, of which neonatal mortality at $141 million is only 4% of that total. For the 500/400/- rule, where the total first year benefits are highest at $6.6 billion, the neonatal mortality is also highest among all rules at $220 million. However, as a percentage of the total, these benefits constitute only about 3.3% for the 500/400/- rule.

ES.5 BENEFIT-COST ANALYSIS OF ALTERNATIVE HAZARD LEVELS

ES.5.1 Results for the Five Abatement Decision Rules

Exhibit ES-5 presents the benefit-cost results for each of the five decision rules. The first comparisons made in this section focus on the net benefits of each decision rule exclusive of testing costs. This orientation makes it possible to distinguish decision rules in terms of the net benefits of abatement. The final comparisons in this section integrate information on the testing costs necessary to implement each of the decision rules.

Net Benefits Excluding Testing Costs

The voluntary optimum clearly sets the standard for judging the performance of the other four decision rules. It generates net benefits of $34.3 billion before testing costs are considered. The net benefits of the voluntary optimum surpass those of the next best alternative by nearly $30 billion. More than 45 million homes undertake abatement, a substantial number especially given the assumption under this decision rule that only homes obtaining positive net benefits initiate abatement. Exhibit ES-6 shows that all but one of the abatements constructed for this analysis would be chosen. Nonrecurrent dust abatement is the leading choice, by far, and low-end soil abatement is a distant second. All other decision rules entail at least two million more paint abatements, primarily because of the recommendation to abate lead-based paint in bad condition.

This conclusion is borne out by the results for the second decision rule, which is based upon the paint condition recommendation. Net benefits are negative (-$17.3 billion) even before testing costs of nearly $15 billion are considered. Virtually all of the 7.1 million abatements conducted under this decision rule are motivated by the assumption that all homeowners having paint in bad condition will undertake the best form of abatement available to them. This decision rule provides a telling example of the tradeoff between conciseness in the form that

Exhibit ES - 5

Benefit-Cost Results for Five Alternative Decision Rules

Decision Rules			Soil (ppm)	Dust (ppm)	Paint mg/cm^2	Nonintact Paint Abatement Recommended	Benefits ($ million)	Abatement Costs ($ million)	Net Benefits (Exclusive of Testing Costs) ($ million)	Testing Costs ($ million)	Net Benefits (Including Testing Costs) ($ million)	Total Number of Abatements (1000s)	Number of Abatements with Negative Net Benefits (1000s)
1.	Voluntary Optimum		-	-	-	No	48,190	13,896	34,294	24,222	10,072	45,165	0
2.	Paint Condition Only		-	-	-	Yes	7,319	24,668	(17,349)	14,987	(32,336)	7,063	6,685
3.	Single Medium Plus Condition	3a.	2,300	-	-	Yes	11,186	28,345	(17,159)	24,222	(41,381)	8,069	7,154
		3b.	-	1,200	-	Yes	32,945	29,646	3,299	24,227	(20,928)	15,602	7,114
		3c.	-	-	20	Yes	7,383	25,014	(17,631)	14,906	(32,537)	7,164	6,786
4.	2-Media Plus Condition	4a.	2,300	1,200	-	Yes	34,920	31,903	3,017	24,227	(21,210)	16,197	7,583
		4b.	2,300	-	20	Yes	11,249	28,689	(17,440)	24,222	(41,662)	8,170	7,255
		4c.	-	1,200	20	Yes	33,009	29,992	3,017	24,227	(21,210)	15,702	7,215
5.	3-Media Plus Condition		2,300	1,200	20	Yes	34,984	32,248	2,736	24,231	(21,495)	16,297	7,684

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm^2 for paint.

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of XRF level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit ES - 6

Distribution of Abatement Choices for Five Alternative Decision Rules

	Decision Rules		Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Number of Homes Abated by Abatement Type (1000s)										
							HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NR D	Total
1.	Voluntary Optimum					No	0	21	0	577	0	0	0	0	0	44,567	45,165
2.	Paint Condition Only		-	-	-	Yes	4,160	2,774	0	0	0	0	114	0	16	0	7,063
3.	Single Medium Plus Condition	3a.	2,300	-	-	Yes	4,160	2,716	0	1,006	0	0	114	0	74	0	8,069
		3b.	-	1,200	-	Yes	4,186	2,731	74	411	276	0	114	18	16	7,777	15,602
		3c.	-	-	20	Yes	4,221	2,814	0	0	0	0	114	0	16	0	7,164
4.	2-Media Plus Condition	4a.	2,300	1,200	-	Yes	4,186	2,672	74	1,006	276	0	114	18	74	7,777	16,197
		4b.	2,300	-	20	Yes	4,221	2,756	0	1,006	0	0	114	0	74	0	8,170
		4c.	-	1,200	20	Yes	4,247	2,770	74	411	276	0	114	18	16	7,777	15,702
5.	3-Media Plus Condition		2,300	1,200	20	Yes	4,247	2,712	74	1,006	276	0	114	18	74	7,777	16,297

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Abatement Codes

HP = High Paint Abatement
LP = Low Paint Abatement
HS = High Soil Abatement
LS = Low Soil Abatement
RD = Recurrent Dust Abatement

HP/HS = High Paint, High Soil Abatements
HP/LS = High Paint, Low Soil Abatements
LP/HS = Low Paint, High Soil Abatements
LP/LS = Low Paint, Low Soil Abatements
NR D = Nonrecurrent Dust Abatement

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of XRF level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

EPA's guidance could take and the resulting inaccuracies in decisions made about abatement. The last column of Exhibit ES-5 shows the number of abatements induced by this recommendation that result in negative net benefits. Of the 7.1 million abatements conducted, 95%, or 6.7 million homes, would be expected to undertake abatement, because it has been recommended, even though it results in negative net benefits.

This outcome is possible not because homeowners are making irrational decisions, i.e., taking steps known to generate negative net benefits, but because they are relying on limited information relative to what homeowners are assumed to have under the voluntary optimum. Under this and all subsequent decision rules, it is assumed that the decision to abate is induced by exceeding one or more hazard levels and not by calculating the net benefits directly. If homeowners had made the calculation, as was assumed in the voluntary optimum, they would not have undertaken the abatement. Clearly the results from the second decision rule show that there is room for finetuning the recommendations made to homeowners in the form of hazard levels. The third decision rule adds one more dimension to EPA's potential recommendations - a hazard level for one of the three media (soil, dust, and paint) while keeping the paint condition criterion of the second decision rule. Two of the cases under this single-medium rule, single hazard levels for soil and paint, also result in negative net benefits and have only slightly lower error rates than the previous decision rule. For soil and paint, 89% and 95% of their respective sets of abatements have negative net benefits.

The prospects for using a single hazard level for dust are more compelling. The net benefits of a dust hazard level of 1,200 ppm are $3.3 billion. The number of homes generating negative net benefits is high, 7.1 million, but the number of abatements induced is also high, 15.6 million, resulting in an error rate of 46%. As Exhibit ES-6 shows, 52% of these abatements (8 out of 15 million) entail some form of dust abatement only. This proportion is lower than that exhibited in the voluntary optimum, where approximately 99% of homes choose some form of dust abatement, because of the high number of homes assumed to undertake paint abatement to comply with the paint condition recommendation.

The fourth decision rule adds yet another dimension to the candidate hazard levels, combining them for two media rather than just one. To satisfy recommendations based upon these hazard levels, such as the case where the soil hazard level is 2,300 ppm and the paint hazard level is 20 mg/cm^2, it is assumed that any homeowner whose home exceeds either one of these thresholds would undertake the best soil and/or paint abatement that makes it possible to go below any binding threshold (as well as to meet the paint condition criterion). Exhibit ES-6 shows the distribution of abatements that would be induced under each set of two-media hazard levels. Under this decision rule, the versions including a dust hazard level are the only ones having positive net benefits before testing costs are considered. In each case, the optimal hazard level for dust is 1,200 ppm, the same as the optimal level for the single-medium rule. However, adding one more dimension to the decision rule constrains household decisions enough to reduce benefits slightly. The net benefits of either two-media rule involving dust are $3.0 billion. The optimal hazard level to combine with a dust hazard level is 2,300 ppm for soil or 20 mg/cm^2 for paint.

The fifth and final decision rule presents the best set of three-media hazard levels. The resulting optimum brings together the hazard levels identified as optimal in the single-medium and two-media decision rules - 2,300 ppm for soil, 1,200 ppm for dust, and 20 mg/cm^2 for paint plus the paint condition criterion - but at the cost of lower net benefits. Adding a third hazard level to the decision restricts the leeway in household choices yet again. This lowers the net benefits by approximately 10% and 20% compared respectively to the best single-medium and two-media cases.

In closing this discussion of the relative net benefits of different decision rules, it is also useful to point out that besides their clear differences in net benefits, the voluntary optimum differs substantially from the other four rules in the number of homes abated. The four decision rules based upon qualitative or quantitative hazard levels induce no more than 16.3 million abatements, of which 7 to 8 million have negative net benefits. The voluntary optimum leads to nearly three times as many abatements - more than 45 million abatements. None entails negative net benefits. This finding raises the possibility that better decision rules could be created that are both implementable, which is the advantage of the decision rules based upon hazard levels, and that lead to positive and substantial net benefits, which the voluntary optimum does. Since the information bases assumed for the first group and for the voluntary optimum differ substantially, it appears that creating a better means for conveying useful information to guide homeowners' abatement decisions could be a productive route for improving upon the decision rules investigated here.

Net Benefits Including Testing Costs

The inclusion of testing costs does not alter the ranking of nine decision rules considered here although it does lower the net benefits. The voluntary optimum still has the highest net benefits ($10 billion). All subsequent decision rules have negative net benefits. The top four among these are based upon a single medium (dust=1200), two media (soil=2300/dust=1200, dust=1200/paint=20), and three media (soil=2300/dust=1200/paint=20). The overall net benefit of any of these decision rules is approximately minus $21 billion, once testing costs are considered. The three lowest-ranking decision rules all have in common that they are based in some way upon a paint hazard level. The qualitative hazard level based upon paint condition criterion ranks seventh, the two-media rule based upon soil and paint ranks eighth, and the single-medium hazard level based upon paint alone ranks ninth. These outcomes and the finding of significant negative net benefits associated with paint abatement highlight the potentially significant influence of the assumptions made regarding the effectiveness and cost of paint abatement.

ES.7 SENSITIVITY ANALYSIS

The number of parameters considered in this report is limited to three items that had a significant likelihood of influencing the policy-relevant outcomes.

First, the report considers the impacts that using low and high unit cost estimates have on the benefits and costs of different decision rules and their optimal hazard levels. These assumptions provide a basis for comparison with the "medium" cost estimates used in the main analysis. This basis establishes possible boundaries for the benefit-cost results and the estimated optimal hazard levels. While the low and high unit cost estimates used in the sensitivity analysis are not the ultimate minimum and maximum values, they were constructed to be representative of the lower and upper ranges of values observed in practice. As such, these unit cost estimates are probably appropriate for testing the boundaries of the benefit-cost analysis.

The bounding exercise for costs indicates that the findings regarding optimal dust and paint hazard levels may not be affected by a better representation of the distribution of abatement costs. Dramatic upward and downward revisions applied simultaneously to all abatements did not change the optimal hazard levels for dust and paint. This does not however categorically rule out revisions in cost estimates which could affect the optimal dust and paint hazard levels.

The sensitivity analysis does show however that the optimal soil hazard level could be susceptible to changes in assumptions regarding the costs of abatement. While the optimal soil hazard level held constant at 2,300 ppm for an upward revision in all abatement costs, it fell to 1,500 ppm when all costs were lowered. Consequently, it appears that the evidence for setting a single hazard level for soil is not clearcut. Instead, a range from 1,500 to 2,300 ppm is supported by the model when bounding cost assumptions are applied.

The second focus of the sensitivity analyses in this report is the discount rate used to express the monetary value of future benefits and costs in contemporary terms. The selection of a discount rate is one of the most commonly debated features of benefit-cost analyses of environmental policies. A rate of 7% was used in the main analysis of this report. An alternate approach, which has been used by the Agency in some other regulatory analyses, involves a two-stage discounting procedure that employs both 3% and 7%. The impact of this approach on the findings of the main analysis was evaluated in the sensitivity analysis.

The sensitivity analysis revealed that the two-stage discounting procedure raises the possibility of a wider range of optimal hazard levels for dust and soil than was implied in the main analysis. The range for the optimal dust hazard levels is from 300 ppm to 1,200 ppm. The range for the optimal soil hazard level is 1,000 ppm to 2,300 ppm. The current analysis cannot categorically support the selection of <u>one</u> hazard level for dust and soil from each of these ranges. However, several things remain constant between the findings of the main analysis and those of the sensitivity analysis. The voluntary optimum is far away the decision rule generating the highest net benefits and the paint condition rule typically the least (and virtually always negative). The types of decision rules that involve hazard levels for dust and soil that have the highest net benefits are generally the same under the two-stage procedure as they are in the main analysis. They are the single-medium dust rule, the two-media rules based upon soil and dust and upon dust and paint, and the three-media rule.

The third focus of the sensitivity analyses in this report considers the possible benefits to adults and children already in the home at the time that abatement takes place. The main analysis presented in this report was based upon a model developed to consider the benefits to children from the time of birth until the age of seven years from the abatement of lead contamination. Not only was the risk assessment focused on this population alone but the behavioral assumptions regarding lead abatement were integrally linked to the impending births of children. This model structure reflects the fact that this population has been considered a primary target for measures to prevent residential exposures to lead-contaminated paint, dust, and soil. However, other populations may also benefit from lead abatement. This sensitivity analysis focuses on existing children in the household who are under the age of seven and on adults in the household.

There are significant barriers to conducting a refined risk assessment for these two populations. Little is known about the size of the IQ benefits to these existing children who only partially avoid lead exposure during the critical seven-year period of intellectual development since abatement was initiated sometime after they were born. For adults, risk assessment is complicated by the lack of information on the relationships between lead levels in paint, soil and dust and blood lead levels for populations over the age of seven. For both populations the current model has shortcomings because abatements are triggered by impending births rather than the circumstances of either existing children or adults. For these reasons, the overall estimates in this sensitivity analysis should be viewed as illustrative only, in light of the unrefined and somewhat arbitrary assumptions needed to generate the supplemental benefit estimates.

This analysis found an optimal hazard level for soil of 1,400 ppm. The optimal hazard level for dust was 400 ppm. The experience with paint hazard levels under this sensitivity analysis reproduced that of the two-stage procedure, where the optimal hazard level was variously 4 or 20 mg/cm^2, depending upon the decision rule, but the highest net benefits were based upon 20 mg/cm^2.

Taken together, the three sensitivity analyses presented in this chapter raise the possibility of a wider range of potentially optimal hazard levels than the findings in the main analysis imply. The optimal dust hazard level may be as low as 300 ppm or as high as 1,200 ppm. The main analysis found a dust hazard level of 1,200 ppm. The optimal soil hazard level may be as low as 1,000 ppm or as high as 2,300 ppm. The main analysis found a soil hazard level of 2,300 ppm. In the main analysis and in the sensitivity analyses, the highest net benefits for paint were associated with a hazard level of 20 mg/cm^2. Finally, a qualitative hazard level based upon paint condition typically entails negative net benefits with the exception of two cases: this particular sensitivity analysis which linked supplemental benefits to paint abatement specifically and, the shortest-term amortization case (10 years) under the two-stage discounting procedure. These two cases still seem rare enough to raise doubts about the desirability of a paint condition criterion given the paint abatement options constructed for this analysis.

ES.8 IMPACTS OF THE PROPOSED RULE

Two types of impacts received primary attention in this report. The first set of impacts relate to the regulatory flexibility of a rulemaking for Section 403. Although no formal regulatory impact analysis has been conducted, since Section 403 does not require specific action to abate residences, this report identifies small entities likely to be induced to conduct abatement activities because of Section 403 and evaluates the available data to quantify any effects on these small entities. Small landlords are the likeliest small entity to be affected. Data on small landlords are not organized in an accessible form for a national analysis. Consequently, further analysis of this impact could require resource-intensive data collection. The second set of impacts relate to concerns about disproportionate burdens being placed on particular categories of households and individuals by actions under Section 403. These impacts were examined using socioeconomic information on a sample of homes and residents from the Department of Housing and Urban Development (HUD) survey of residential lead contamination that was a basis for the benefit-cost analysis in this report, as well as income information from the U.S. 1990 Census. The results of this equity analysis are discussed below.

Existing lead-based paint hazards are a risk to all segments of our population living in pre-1980 housing. However, the HUD survey does indicate that some segments of our society are at relatively greater risk than others. In particular, the residents of older, low cost housing are exposed to a disproportionately greater share of lead potential hazard than other housing units. The housing stock in the North-East (and to some extent the Mid-West) includes a larger share of such units than other regions, creating a regional inequity in the prevalence of the problem. Because poorer people usually occupy low-cost housing, the hazards disproportionately fall on lower income sub-populations (especially households living in poverty, with annual incomes below $10,000), creating an income inequity. Finally, the relatively larger share of African-Americans in the lower income groups results in racial inequity.

Although the baseline risks from lead-based paint disproportionately fall on poorer sub-populations, abatement may well be more likely to occur in housing units occupied by wealthier households. Most of the abatements under the Lead-Based Paint Hazard Reduction Act will be voluntary, and wealthier households are more likely to have the means to abate an existing problem in their home, or avoid moving into a housing unit with a known lead-based paint hazard. An analysis conducted for this report shows that income constraints could have a significant impact on the number of abatements conducted as the result of promulgating hazard levels under Section 403. When abatement decisions are constrained by income limits, the number of abatements undertaken falls substantially, raising the possible dilemma that some necessary abatements will not be undertaken because of income constraints.

However, determining the ultimate implications for equity is more complicated. The abatements that are not affordable tend to be the ones that have negative net benefits. Although unaffordable, such abatements are already questionable from the perspective of social welfare. Net benefits actually rise, and in certain cases become positive, when the number of abatements are constrained by limits on income. This finding underscores how any policy intended to address income obstacles to abatement should be paired with an effort to fit each house with a suitable abatement choice. This analysis also shows that if subsidies were used to enable abatements with positive net benefits that would otherwise be prohibited by income constraints, the funding needs could be significant. Approximately $45 to $319 million would have to be spent annually over 50 years.

ES.9 CONCLUSION

The highest net benefits identified in this analysis derive from determining the best abatement for each individual home. Once testing is taken into account, net benefits of $10 billion are possible. This approach, known as the voluntary optimum, takes the concept of hazard levels to the extreme since it is essentially equivalent to setting hazard levels for each and every combination of paint condition and soil, dust, and paint levels, among other factors.

Among the class of more feasible sets of hazard levels, the primary candidate for consideration is a single dust hazard level of 1,200 ppm, given the assumption that an additional recommendation will be made to homeowners that non-intact lead-based paint be abated. This hazard level generates the highest net benefits among all of the alternative sets of hazard levels. Although the highest, the overall net benefits of this hazard level are negative (-$21 billion) once testing costs of $24 billion are taken into account. Slightly lower net benefits can be achieved by combining this dust hazard level with a soil hazard level of 2,300 ppm and a paint hazard level of 20 mg/cm^2. For any of these sets of candidate hazard levels it appears that the net benefits are substantially lower because of the abatement aimed at non-intact lead-based paint.

The support for these specific hazard levels is very consistent across different decision frameworks within the main analysis but the range of possible hazard levels may be broadened once the results of sensitivity analyses or other decision factors are taken into account. The sensitivity analyses indicate that the optimal dust hazard level could be as low as 300 ppm and that the optimal soil hazard level could be as low as 1,000 ppm. The validity of these lower estimates hinges on the weight given to the alternate assumptions made in the sensitivity analyses. Other alternative hazard levels besides those cited above may also be contenders if other criteria besides economic efficiency will be considered in EPA's decisionmaking. One such possibility is to choose hazard levels to keep the risk of exceeding a blood lead concentration of 15 ug/dl below 5%. This analysis indicates that taking this approach may be costly. The net benefits of one such set of hazard levels (soil=500/dust=400) are negative (-$19 billion) before testing costs are included.

1. INTRODUCTION

1.1 PROVISIONS OF RULE

Section 403 in Title IV of the Toxic Substances Control Act (TSCA) directs EPA to promulgate regulations that identify lead-based paint hazards, lead-contaminated dust, and lead-contaminated soil. Section 403 is one portion of the Residential Lead-Based Paint Hazard Reduction Act of 1992 (the Act), which requires that the United States Environmental Protection Agency (EPA), the Department of Housing and Urban Development (HUD), and other Federal Agencies develop a national strategy to build the infrastructure necessary to eliminate lead-based paint hazards in all housing. Clearly identifying what constitutes a lead-based paint hazard is an important step in encouraging effective action to evaluate and reduce the lead-paint hazards in the Nation's housing stock.

The Act establishes Federal grants and other programs that create a partnership among all levels of government and the private sector in order to best mobilize national resources to reduce lead-based paint hazards. Many of the activities involving the identification of lead-based paint hazards in the Act (including inspections and risk assessments by appropriately trained and certified personnel, as well as abatement of any hazards identified) are voluntary. However, in certain circumstances the activities are required. Section 403 is consistently used throughout the Act to identify those paint, soil and dust conditions that are affected by the Federal and state programs included as a part of the national strategy to eliminate the hazards of lead-based paint in residences. Exhibit 1.1 summarizes the provisions of the Act that directly rely on the §403 identification of a hazard.

1.2 STATUTORY AUTHORITY

On October 28, 1992 Congress enacted the Housing and Community Development Act of 1992, which includes 16 separate Titles. Title X of that Act is entitled the Residential Lead-Based Paint Hazard Reduction Act of 1992. Title X is composed of five subparts, including Subtitle B which amends TSCA by adding a new Title IV-Lead Exposure Reduction. TSCA Title IV includes twelve sections, from §401 through §412. *Section 403 - Identification of Dangerous Levels of Lead* is very brief; the complete text reads as follows:

> "Within 18 months after the enactment of this title, the Administrator shall promulgate regulations which shall identify, for purposes of this title and the Residential Lead-Based Paint Hazard Reduction Act of 1992, lead-based paint hazards, lead-contaminated dust, and lead-contaminated soil."

The Section 403 identification of lead-based paint hazards is used not only in Title IV of TSCA, but throughout the Act as the basis for determining the appropriate response to the

Exhibit 1-1

Relationship of §403 Identification with Other Provisions of the Lead-Based Paint Hazard Reduction Act

Section	Affected Housing Stock or Entity	Relationship
§1011(a)	Affordable non-public housing that is not federally owned or assisted housing	§403 Identification used to establish eligibility for receiving HUD grants for interim controls or abatement of lead-based paint hazards.
§1012	Various housing receiving assistance under the Cranston-Gonzalez National Affordable Housing Act	1) §403 Identification used to require reduction of hazards in course of rehabilitation projects receiving less than $25,000 per unit in federal funds, and abatement of hazards in rehabilitation projects receiving more than $25,000 per unit. 2) §403 Identification used to establish eligibility for receiving federal funds for interim controls or abatement of lead-based paint hazards. 3) §403 Identification used to establish eligibility for including inspection and abatement costs in determining maximum monthly rents in federally assisted rental property.
§1013	Federally owned housing being sold	1) Housing built prior to 1960: Inspection and REQUIRED abatement of lead-based paint hazard (as identified by §403). 2) Housing built between 1960 and 1978: Inspection and written notification to buyer of all lead-based paint hazards (as identified by §403)
§1014	Low-income housing units under jurisdiction of Cranston-Gonzalez National Affordable Housing Act.	§403 Identification used to estimate number of housing units in a jurisdiction occupied by low-income families that have a lead-based paint hazard. Information shall be used in preparing a housing strategy .
§1015	Private housing.	§403 Identification used by Inter-Agency Task Force to recommend programs and procedures for financing inspections and abatements.

Section	Affected Housing Stock or Entity	Relationship
§1017	Federally supported inspections, risk assessments, interim controls and abatements	§403 Identification used in Guidelines for conducting federally supported lead-based paint hazard reduction.
§1018	Sale or lease of all housing stock constructed before 1978.	Requires notification to buyer of any known lead-based paint hazards (as identified by §403). Buyer has right to perform inspection before being obligated by contract for sale or lease.
§1021 TSCA Title IV, §402	Persons offering to eliminate lead-based paint hazards.	Training and certification requirements for all persons involved with identifying and eliminating lead-based paint hazards (as identified by §403).
§1021 TSCA Title IV, §405	Information on identifying and eliminating lead-based paint hazards.	1) Clearinghouse and hotline to provide information on identifying, reducing and eliminating lead-based paint hazards (as identified by §403). 2) Establish protocols and performance characteristics for products sold to reduce or eliminate lead-based paint hazards (as identified by §403).
§1021 TSCA Title IV, §406	Lead Hazard Information Pamphlet.	Required pamphlet to explain lead-based paint hazards (as identified by §403) and approved methods to eliminate those hazards.
§1021 TSCA Title IV, §408	All executive, legislative and judicial branches of the federal government having jurisdiction over property, or engaged in activities that may result in a lead-based paint hazard.	All requirements in Lead-Based Paint Hazard Reduction Act of 1992 shall apply to all federal departments, agencies and instrumentalities.

existence of a lead-based paint hazard. Section 1004(15) defines a lead-based paint hazard as:

> "The term "lead-based paint hazard" means any condition that causes exposure to lead from lead-contaminated dust, lead-contaminated soil, lead-contaminatedpaint that is deteriorated or present in accessible surfaces, friction surfaces, or impact surfaces that would result in adverse human health effects as established by the appropriate Federal agency."

This definition is repeated in TSCA Section 401(10), except the responsibility to establish what constitutes a hazard is clearly given to EPA;

> "...adverse human health effects as established by the Administrator under this Title."

The proposed Section 403 identification of lead-based paint hazards is used throughout the Act to establish requirements and eligibility for programs dealing with the national strategy for reducing the risks of lead-based paint.

Section 1004 (16 & 17) goes on to define lead-contaminated dust as:

> "surface dust in residential dwellings that contains an area or mass concentration of lead in excess of levels determined by the appropriate Federal agency to pose a threat of adverse health effects in pregnant women or young children"

and lead-contaminated soil as:

> "bare soil on residential real property that contains lead at or in excess of the levels determined to be hazardous to human health by the appropriate Federal agency."

1.3 PURPOSE AND CONTENTS OF REPORT

The purpose of this regulatory impact analysis is to evaluate the effects of defining various lead hazard levels in paint, soil and dust. The primary impacts are the costs of lead abatements conducted in response to the regulation and the health benefits that accrue to children from a reduced exposure to lead. The report follows the standard outline for a regulatory impact analysis. Chapter 2 describes past regulatory actions to reduce risks from lead. Chapter 3 details the method used to evaluate the risks to children from lead exposure and explains the method for quantifying the benefits of reduced exposure. This chapter also defines the market failure that indicates a need for federal regulation, presents regulatory options that might be considered, and gives an overview of the analytic approach. The costs of lead testing and abatement are shown in Chapter 4 along with the total cost results for the regulatory options under consideration. Chapter 5 presents the quantified benefits of the regulatory options. The benefit-cost analysis in Chapter 6 explains how the regulatory options were identified based on the value of the net benefits and presents results for each of the possible options. Chapter 7 presents sensitivity analyses to characterize the model uncertainties. The final chapter (Chapter 8) indicates the data available for evaluating the impact of this regulation on small entities (businesses and governments), discusses the regulatory impacts on trade, technological innovation and equity, and presents equity analyses for adults and children.

2. REGULATORY BACKGROUND

2.1 INTRODUCTION

2.1.1 Lead as a Public Health Problem

Exposure to lead is one of the most serious public health problems currently facing the United States (ATSDR, 1988). Lead's advantages, including its malleability, resistance to corrosion, good insulation, and low cost, have made lead attractive for many applications; lead has been used in gasoline, ceramics, paint, and several other products. These uses have resulted in lead's release to and distribution in all environmental media, which has complicated efforts at reduction (ATSDR, 1988). Much of lead in the environment is accessible to humans through a variety of exposure pathways, and since it does not degrade, continued use of lead results in accumulation in the environment. Human exposure to lead is of concern because it interferes with the normal functioning of cells causing a range of toxic effects in the nervous, red blood cell, and kidney systems (ATSDR, 1988). Fetuses and young children exposed to lead are especially at risk from damages to the developing brain and nervous system (CDC, 1991).

Knowledge of some of lead's negative health effects dates back about 2000 years. Reproductive and developmental effects of lead were recognized in the 18th and 19th centuries in the United States in female lead workers and wives of lead workers. These women demonstrated problems including sterility, spontaneous abortion, stillbirth, and premature delivery, and their offspring exhibited high mortality, low birth weight, convulsions and other effects. This recognition resulted in better industrial hygiene which in turn, reduced reproductive problems (ATSDR, 1988).

The prevalence of direct lead poisoning in children was first examined in Australia in the 1890s and traced to exterior lead-based paint (ATSDR, 1988). In the U.S., physicians eventually defined lead poisoning in children as a clinical entity in the early 20th century after a study reported that lead caused acute encephalopathy in a number of children. In the 1930s and 1940s, epidemiologic data on childhood lead poisoning began to expand and accelerated through the 1960s. Rudimentary screening of children in the 1950s and 1960s clearly showed that they were being exposed to excessive amounts of lead. Prevalence of lead poisoning was especially high among inner city youth. More massive screenings in the 1970s resulted in the recognition of lead poisoning as a widespread public health problem (ATSDR, 1988).

Lead exposure's prominence as a public health concern has been due to increased blood lead levels. Although the average blood lead levels in the U.S. population are estimated to have dropped in the last two decades (U.S. EPA 1989b, 1991a), levels are about 15 to 30 times higher in some U.S. populations than the pre-industrial average of about 0.5 μg/dl (ATSDR, 1988).

The recognition of lead's adverse effects has resulted in lowering the blood lead level that triggers medical intervention. In 1970, the U.S. Public Health Service published guidelines that set the level at 60 μg/dl (CDC, 1991). Shortly thereafter, the CDC set the guidelines at 40 μg/dl, then revised the recommendations to 20 μg/dl, and finally to set them at the current level of 10-14 μg/dl in 1991. Levels higher than this range trigger various intermediate actions; a child with a blood lead level between 15-19 μg/dl should have nutritional and education interventions; and a blood lead level greater than 20 μg/dl should prompt medical evaluations and environmental investigations (CDC, 1991).

The following sections focus on regulations designed to decrease exposure to lead. Section 2.2 discusses laws and regulations designed to decrease exposure to lead in a variety of media, including products, releases, and past use of lead in plumbing. Section 2.3 focuses solely on efforts at the federal, state and local levels to decrease exposure to lead remaining in residential areas (including lead in paint, dust, and soil).

2.2 REGULATION OF LEAD PRODUCTS, ENVIRONMENTAL AND WORKPLACE RELEASES OF LEAD, AND LEAD IN DRINKING WATER

Lead content in some products has been prohibited or restricted. Also, environmental releases to air and water and in waste have been controlled. OSHA has set limits on workplace concentrations. In addition, efforts have been made to remediate exposure to lead already in the environment from its use in drinking water systems.

2.2.1 Lead in Paint

In the 1950s, the paint industry voluntarily restricted sale of paint with lead content greater than one percent (Mushak and Crocetti, 1990). Subsequently, the Lead-Based Paint Poisoning Prevention Act, enacted in 1971, prohibited the use of paint with greater than one percent lead (by weight of nonvolatile solids) in certain federally-owned or federally-assisted housing (HUD, 1990). As a result of 1976 amendments to this Act, lead paint was redefined as paint containing more than 0.06% lead by weight (HUD, 1990). In 1978, the U.S. Consumer Product Safety Commission banned both the sale of such lead-based paint to consumers and its use in residences or on other consumer-accessible surfaces (16 CFR 1303).

2.2.2 Lead in Gasoline

The Clean Air Act of 1970 (CAA) first controlled the use of lead in gasoline because it rendered catalytic converters inoperative. In response, the use of lead in gasoline declined significantly during the 1970s. In 1986, the U.S. acted to phase out the use of lead in gasoline entirely (51 FR 24606). Currently, the U.S. restricts the amount of lead allowed per liter of leaded gasoline to 0.026 grams. Effective in 1988, the United States also required all new light duty vehicles and trucks, motorcycles and heavy duty gasoline engines to operate on unleaded gasoline. (Unleaded gasoline is defined as gasoline containing no more than 0.01 g/l of lead.) In addition, as of 1992, motor vehicle engines and non-road engines that require leaded gasoline are prohibited. As of December 31, 1995, a total ban on leaded gasoline and lead gasoline additives for highway use will be in place.

2.2.3 Other Lead-based Products

The U.S. canning industry has voluntarily phased out the use of lead solder in food cans since alternative, affordable processes for sealing the seams of tin containers are available (FDA, 1992a). U.S. industry and the U.S. Food and Drug Administration have also undertaken efforts to control lead exposure from ceramic ware (FDA, 1991), foil on wine bottles, and crystalware (FDA, 1992b). Eight U.S. states have adopted legislation to limit the levels of lead in packaging materials (EPA, 1991b).

2.2.4 Environmental and Workplace Releases of Lead

Under authority of the Clean Air Act, EPA has established standards of performance designed to limit emissions of air pollutants from lead smelting and processing facilities. In addition, lead emissions from these and other industries are controlled via facility-specific permits written by states. These permits are designed to reduce emissions to the extent needed to meet EPA's national ambient air quality standard for lead of 1.5 $\mu g/m^3$ (quarterly average), established in 1978 (43 FR 46246).

Under the Clean Water Act, federal effluent guidelines and pretreatment limits for lead-containing effluents have been established for over 20 industries. These limits help achieve state-promulgated surface water quality standards (which may be based on water quality criteria published by EPA). The effluent limits are implemented by states through facility-specific permits and, depending on state water quality standards, may be more stringent than federal effluent requirements.

Releases of lead as solid waste are regulated under the Resource Conservation and Recovery Act (RCRA). A waste is defined as hazardous if, when tested, the leachate from the waste contains more than 5 ppm (40 CFR 261.24). In addition, certain lead-containing wastes are separately listed as hazardous wastes. All of these wastes must be properly managed and disposed (40 CFR 260-270).

EPA has also initiated a voluntary program to reduce lead emissions, based on the Toxics Release Inventory reporting. This project, called the "33/50 Program", encourages industry to curtail emissions of 17 toxic pollutants, including lead (U.S. EPA, 1992). The specific aim of the project is to obtain commitments from companies to voluntarily reduce emissions, effluents and offsite transfers of the subset of the 17 pollutants that are applicable to their operations in two phases -- 33 percent by 1992 and 50 percent by 1995 -- using 1988 as the baseline year. As of 1992, 850 companies had agreed to participate in this program.

Efforts to reduce exposure to lead releases in the workplace have included setting permissible workplace air concentrations of lead and permissible blood lead levels in workers (Niemeier, 1991). The current Permissible Exposure Limit (PEL) is 50 $\mu g/m^3$ for most industries except the construction industry (OECD, 1993). Under the Residential Lead-based Paint Hazard Reduction Act, passed in October 1992, OSHA is required to issue interim regulations lowering the limit for the construction industry (ACELP, 1993).

2.2.5 Lead in Drinking Water

Exposure to lead in drinking water has continued because of past use of lead in plumbing. EPA has acted to reduce these exposures through recent comprehensive measures (Mushak and Crocetti, 1990). In rules promulgated in 1991, the U.S. EPA outlined new treatment requirements for drinking water systems (56 FR 26460). The regulation requires tap water sampling from high risk homes (e.g., lead service lines or lead soldering installed since 1982). If at least 10 percent of home tap samples exceed 15 μg/l (the "action level"), corrosion control treatment and public education is required. Replacement of lead service lines is required if corrosion control fails to bring water lead levels below the "action level." EPA has also issued a maximum contaminant level goal of zero for lead in drinking water.

2.2.6 Resulting Reduction in Blood Lead Levels

These regulations and other efforts have clearly reduced exposure and blood lead levels significantly. Although no recent national study has measured human blood lead, it is estimated that average concentrations have dropped over the last two decades from about 15-20 μg/dl to approximately 5 μg/dl (EPA, 1991a). In particular, reductions of lead in gasoline have contributed dramatically to reductions in blood lead levels. Several studies have specifically examined the relationship between blood lead and the lead content of gasoline, and have found a strong positive correlation (Schwartz and Pitcher, 1989, Rabinowitz and Needleman, 1983). Annest et al. (1983) noted a 37 percent drop in blood lead levels from 1976 to 1980 correlated with a reduction in gasoline lead, while Schwartz and Pitcher (1989) estimated that as much as 50 percent of blood lead in the U.S. in the late 1970's may have been attributable to lead in gasoline.

Reductions in dietary lead have also contributed to declining exposures. Dietary lead intake for a two-year-old child has dropped from about 53 μg/day in 1978 to an estimated 13.1 μg/day in 1985; comparable declines have been seen in adults (U.S. EPA, 1989b). These trends are attributable to the reduction in gasoline lead emissions (and resulting reductions in deposition of lead from air to soil) and the voluntary phaseout of lead-soldered cans by U.S manufacturers since the 1970s. It can be calculated that these changes in lead exposure from food have led to reductions of 1-2.5 μg/dl in average blood lead levels (U.S.EPA, 1989b).

2.3 EFFORTS TO REDUCE LEAD-BASED PAINT, DUST AND SOIL IN RESIDENTIAL AREAS

One of the largest remaining lead exposure sources for children is existing reservoirs of lead-based paint, dust and soil present in many residential areas (ATSDR, 1988). In an effort to reduce exposure to residential lead hazards, regulatory efforts have been increasing for several years to address these hazards.

2.3.1 Current Estimates of Exposure

Although new paint containing lead was banned for use in residences in 1978, exposure to existing lead-based paint has continued due to prior uses in residential and other buildings. In addition, leaded house paint can contribute to lead in interior dust and soil. There also remains a significant soil burden of lead from leaded gasoline and lead smelter emissions.

Several studies have demonstrated positive correlations between blood lead levels and lead in paint, soil and dust (Gilbert et al., 1979 as cited in CDC, 1991; Charney et al., 1980, Charney et al., 1983, and Bellinger et al., 1986 as cited in HUD, 1990; Clark et al., 1991). Exposures are especially high in children. In a 1988 Report to Congress on the extent of lead poisoning in children, ATSDR stated that the existing leaded paint in U.S. housing and public buildings is "an untouched and enormously serious problem" (ATSDR, 1988). The Centers for Disease Control conveys the seriousness of home lead exposure as a contributor to elevated childhood blood lead by stating that lead poisoning exists in our society primarily because of exposure in the home (CDC, 1991). However, since only about 5 percent of children are screened, most children with lead poisoning probably are not identified. Infants and toddlers are especially susceptible to lead in the home because they may ingest lead paint chips, dust and soil and because of the way they metabolize lead. Older children, up to at least 8 years old, are also at increased risk (ATSDR, 1988).

Exposure continues mainly from paint in older homes, since houses built after 1978 are presumed to be free of lead paint. A 1987 HUD survey of 284 homes built before 1980 indicated that, for privately owned houses, an estimated 57.4 million (74%) of all pre-1980 private homes have some lead-based paint (HUD, 1990). Of these units, an estimated 9.9 million units have families with children younger than seven years old. These units (with both lead-based paint and young children) represent 71 percent of all pre-1980 housing units occupied by families with children under seven. Houses built before 1940 have the highest prevalence of lead-based paint in either the interior or exterior (90% of all pre-1940 houses), whereas 62% of the houses built between 1960 and 1979 contain lead-based paint. Of the homes with lead paint, 3.8 million homes in which young children live have peeling paint or excessive lead-containing dust.

A significant number of public housing units also contain lead paint. A small survey of public housing conducted in 34 cities in 1984 and 1985 show that in housing built before 1950, 81 percent of the units sampled contained lead-based paint, whereas a smaller proportion (48%) of the sampled units built between 1960 and 1977 had leaded paint (HUD, 1990). Preliminary results from the public housing portion of the HUD survey conducted in 1987 indicate a greater percent of public housing with lead paint (HUD, 1993); about 91% of the sample of 97 public housing units investigated had lead-based paint somewhere in the interior or exterior of the unit, although many with lead-based paint had fairly low levels (HUD, 1993). Families of all socioeconomic classes may live in older housing, and thus be exposed to lead paint (ATSDR, 1988). However, families with the lowest incomes are disproportionately found in older housing (ATSDR, 1988).

2.3.2 Federal Regulatory Activities to Decrease Exposure to Lead-Based Paint in Existing Housing

Federal regulatory efforts and guidelines to limit exposure to lead-based paint in the existing housing stock have evolved over the past twenty years. The following two sections chronicle these activities in detail.

<u>The Lead-based Paint Poisoning Prevention Act and Amendments</u>

The Lead-based Paint Poisoning Prevention Act of 1971 (LBPPPA) and subsequent amendments (1973, 1976, 1987, and 1988) have resulted in a number of federal regulatory activities to reduce exposures and risks from lead paint in housing. In addition to setting limits on the use of lead paint as described above, the Act established grants for lead-poisoning screening and treatment, and required a report to Congress on methods of abatement (HUD, 1990).

Abatement of Lead-based Paint Hazards in Federally-associated, Public and Indian Housing. The 1973 amendments required HUD to eliminate, as much as was practical, hazards of lead-based paint poisoning in pre-1950 housing covered by housing subsidies and applications for mortgage insurance and in all pre-1950 federally owned housing prior to sale. HUD acted by issuing regulations to warn tenants and purchasers of HUD-associated housing of the "immediate hazard" of lead-based paint (defined as conditions associated with deteriorating lead paint surfaces). A 1983 court action resulted in broadening the definition of "immediate hazard" to include intact paint; this definition was subsequently signed into law in 1987. In regulations issued by HUD in 1986 and 1987, the construction cutoff date was changed from 1950 to 1973 in most cases. HUD again changed the cutoff date in response to 1987 amendments to the LBPPPA; the new date became 1978 for all programs (HUD, 1990). The 1988 Amendments to the LBPPPA specified the level which defines a lead paint surface as 0.5% by weight or 1.0 mg/cm^2 (AECLP, 1993). HUD has also promulgated rules to eliminate lead paint hazards in public and Indian housing (Mushak and Crocetti, 1990). In these types of units that have children younger than 7 years old, inspections for defective paint surfaces are required; if a child has an elevated blood lead level, then the house must be inspected for chewable and defective surfaces, and abatement is required in dwellings, common areas, or public child care facilities within the public housing.

Grants. The LBPPPA authorized funding for States and cities to conduct extensive screening programs to identify lead-poisoned children, refer them for medical treatment, investigate their houses for lead, and require abatement (HUD, 1990).

Research and Reports to Congress. The 1971 LBPPPA required a report to Congress on the "nature and extent of the problem of lead-based paint poisoning" and methods of removal. Then, the 1987 amendments required an extensive research and demonstration project on lead-paint testing and abatement technologies in HUD-owned housing, as well as additional reports to Congress (HUD, 1990). In response to another mandate of the 1987 amendments, HUD conducted a survey of the distribution of lead-based paint in the nation's housing stock and submitted a report on the results for privately-owned housing to Congress in a comprehensive plan for abating paint in private housing. Additional amendments in 1988 required a demonstration of abatement techniques in public housing as well as a comprehensive plan to address abatement in public housing (HUD, 1990).

Interim Guidelines. In response to a need for better guidance on testing, abatement, remediation, disposal, and worker protection, HUD published interim guidelines related to these activities and issues in 1990; these guidelines were specifically related to the concerns of public housing agencies. The guidelines have been used subsequently in the abatement demonstration in public housing (HUD, 1990; EPA, 1993).

The Residential Lead-based Paint Hazard Reduction Act

The most recent statutory activity related to the reduction of lead paint hazards is the enactment of the Residential Lead-based Paint Hazard Reduction Act in October of 1992. Also known as Title X of the Housing and Community Development Act of 1992, this Act amends sections of the LBPPPA and adds a new section (Title IV) to the Toxic Substances Control Act (TSCA), in addition to other important new provisions. Described as "the most comprehensive and significant lead poisoning prevention legislation in more than two decades" (AECLP, 1993), the Act aims to provide attainable goals for reducing lead hazards in residential settings by targeting specific housing in the greatest need of abatement (AECLP, 1993).

Federally-owned and assisted housing. Title X allows for more targeted lead hazard evaluation and reduction activities in federally-owned and assisted housing (AECLP, 1993). Whereas provisions under the 1987 amendments to LBPPPA indicated that any and all houses built before 1978 that contain lead-based paint constitute hazards that may be acted upon, Title X provides a more strategic approach to reducing the hazards from lead-based paint. This approach involves requirements for risk assessments, inspections, and interim controls for pre-1978 housing (targeted housing) and also requires deadlines for action. Title X also extends federal lead-based paint requirements to all housing that receives more than $5,000 in project-based assistance under any federal housing or community development program (in addition to the federally assisted and insured houses covered under previous Acts) (Section 1012); inclusion of these houses significantly expands the universe of federally-insured and assisted housing subject to lead-based paint related requirements (AECLP, 1993).

Additional provisions apply to federally-owned housing being sold (AECLP, 1993). Properties built prior to 1978 must be inspected and their condition disclosed to the prospective buyer. Units built before 1960 that have lead-based paint (defined as priority housing) must be abated (Section 1013).

Private housing. Private housing has received greater focus under Title X than under LBPPPA. Although states, local governments or common law still determine whether landlords provide safe housing, Title X includes several features to encourage evaluation and reduction of lead-based paint hazards in private housing. First, Title X formalized into law a grant program run by the Department of Housing and Urban Development for reducing lead-based paint hazards in low-income privately owned housing. Grants awarded to state and local governments for this purpose include $47.7 million for 1992 and $100 million for 1993 (Section 1011). Title X authorizes an increase of $250 million in grants for 1994, to be determined by subsequent Appropriations Acts (AECLP, 1993).

Other Title X provisions also affect targeted private housing (AECLP, 1993). These mandates include integration of lead hazard evaluation and reduction into local housing programs, and certain disclosure and warning requirements to be met at the time of sale or rental of any pre-1978 housing unit (Sections 1014 and 1018). The Act also requires establishment of a national task force on lead-based paint hazard reduction and financing; this group is to be made up of an array of groups involved in housing, real estate, insurance, lending, abatement, and other groups (Section 1015).

Safety of residents and workers. This law requires promulgation of a number of regulations addressing the safety of workers undertaking interventions and safety of families who live or will live in treated housing. Section 1021 amends TSCA by adding a new Title IV, which primarily addresses EPA requirements for contractor training and certification. This regulatory analysis supports the development of the regulation that responds to TSCA § 403 (in § 1021); this regulation requires EPA to define a "lead-based paint hazard" and dangerous levels of lead in dust and soil. EPA must also set standards of minimum performance for lead-based paint activities and ensure that individuals engaged in activities are trained, that training programs are accredited, and that contractors are certified (TSCA § 402). HUD and EPA are to assist in funding state certification and training programs and to issue standards for a model state program (TSCA § 404). In addition, EPA must assure that a program is in place to certify environmental sampling laboratories and must provide for development of products and devices for testing and abatement (TSCA § 405). To further protect abatement workers (and other construction workers), OSHA is required to issue interim final regulations on the maximum permissible limit of lead in air at construction sites (§ 1031 and 1032).

Education regarding lead paint hazards. Title X also mandates a variety of public educational efforts. A hotline designed to inform the public about lead hazards was set up soon after passage of the 1992 Act. The National Clearinghouse on Childhood Lead Poisoning was then established in April, 1993. The Consumer Product Safety Commission, in coordination with EPA, is also developing educational materials such as information to be displayed by hardware stores that sell paint removal products (AECLP, 1993).

Research and development. A variety of research is also required under Title X. EPA is required to conduct a study on the hazard potential of renovation and remodeling and must publish results by April, 1995 (Section 1021: TSCA 402). The new TSCA Section 405 requires a study on the methods to reduce occupational lead exposures and a study of the sources of lead exposure in children to be issued as a report to Congress. Section 1051-1053 of Title X requires research and evaluation on various lead-based paint testing and abatement topics; five million dollars is appropriated for this research in each of the years 1993 and 1994.

2.3.3 Federal Guidelines and Other Activities Related to Lead in Soils and Dust

Guidelines for levels of lead in soil and dust

As mentioned above, EPA is required to determine dangerous levels of lead in dust and soil under Title X. In the meantime, however, interim guidelines for abatement of lead-based paint in housing set by the Department of Housing and Urban Development recommend clearance levels for lead in household dust of 200 $\mu g/ft^2$ for floors, 500 $\mu g/ft^2$ for window sills and 800 $\mu g/ft^2$ for window wells (HUD, 1990). No guidelines currently exist for residential soils, but EPA has adopted interim guidance for levels to be attained at remediated hazardous waste sites. The interim guidance recommends soil concentrations between 500 and 1000 mg/kg (EPA, 1989a).

Other activities

Under authority of Title III of the 1986 Superfund amendments, EPA has funded projects in Boston, Baltimore, and Cincinnati to test the health effects of abating soil with high lead content in residential areas. This research is being considered in developing the final guidance on soil clearance levels.

2.3.4 State and Local Programs to Reduce Exposure to Lead-based Paint, Dust and Soil

Activity to address lead-based paint hazards has recently increased at the state and local levels, although certain areas (e.g., Baltimore) have had programs in place for many years. The following sections describe typical features in lead poisoning prevention projects and discuss notable state and local systems.

State activities

In 1991, CDC issued a policy statement on lead-poisoning prevention that included several recommendations. A survey was then administered to state officials in 1992 to determine their lead poisoning prevention and lead abatement activities and whether they had adopted the CDC recommendations. States did not respond to every question in the survey. For one question, thirty-seven of 46 responding states indicated that they were coordinating prevention activities between housing and environmental agencies (Fischer and Boyer, 1993). Nineteen of 47 states had a program at the state level for monitoring health and environmental follow-up of children with high blood lead levels. Twenty-four of 28 responding states reported the ability to assure medical and environmental follow-up for more than 50% of children with blood lead levels of 20 µg/dl and greater (Fischer and Boyer, 1993).

Several states have requirements and standards specifically related to lead abatement. Seventeen states have authority to require abatement or remediation of lead hazards and eighteen have adopted abatement standards (Farquhar and South, 1993). At least twelve states have specific standards for soil (ranging from 100 ppm to 1000 ppm) and twelve states can require abatement of lead in soils (Farquhar and South, 1993; Mn Dept. of Hlth, n.d.). Table 2.1 lists standards for paint, dust and soil adopted by several states; these standards represent levels that trigger abatement or remediation and/or levels that must be achieved during abatement or remediation. In cases where abatement has been required, states have consistently ordered removal of paint up to five feet from the floor in order to protect children (HUD, 1990). The principal sources of funding for abatement (as indicated by 23 states) have been local funds and money spent by owners of property with lead hazards (Fischer and Boyer, 1993). However, HUD grants for 1992 and 1993 are specifically slated for lead abatement in California, Massachusetts, Minnesota, New Jersey, Rhode Island, and Wisconsin (NCLSH, 1993; AECLP).

Traditionally, state activities addressing lead-based paint and lead poisoning in children have not been extensive. Blood screening has been the primary program activity of states, usually provided by walk-in clinics or special screening campaigns. The extent of screening, however, varies widely because of budget constraints (HUD, 1990). Environmental intervention has often only occurred after identification of a poisoned child. In states that have authority to require abatement, the authority usually occurs through negotiation so as not to cause undue financial hardship. In addition, states have not usually provided funds for abatement activities recommended as a result of medical and environmental intervention (HUD, 1990).

Exhibit 2-1

Standards for Paint, Dust, and Soil Adopted by Selected States

State	Paint	Dust ($\mu g/ft^2$)	Soil (ppm)	Reference
Massachusetts	0.5% by weight or 1.2 mg/cm²	200 (floor) 500 (window sill) 800 (window well)	1000 by weight	105 CMR 460.020; 460.170
Maryland	0.5% by weight or 0.7 mg/cm²	200 (floor) 500 (window sill) 800 (window well)	none	COMAR 26.02.07
Minnesota	0.5% by weight or 1.0 mg/cm²	80 (floor) 300 (window sill) 500 (window well)	100 by weight	Mn Dept of Hlth, 1993
Rhode Island	0.05% or 500 ppm on non-intact surfaces	200 (floor) 500 (window sill) 800 (window well)	1000 by weight	R 23-24.6-PB

While most states generally have had limited programs, Maryland and Massachusetts have traditionally had more extensive systems (HUD, 1990). In 1972, Massachusetts established the first statewide program. Subsequently, Massachusetts has had some of the highest screening penetration rates in the country (Prenney, 1987). The features that distinguish both the Maryland and the Massachusetts programs include the following (HUD, 1990):

- Both states have a high level of interagency involvement which provides an effective mechanism for policy development and implementation. Before formal legislation was passed, each state formed a policy task force representing a cross-section of agencies. This multidisciplinary approach was then written into legislation in each state.

- Both states have methods of enforcing abatement requirements. In Massachusetts, property owners who fail to comply with abatement orders are liable for actual and punitive damages. Under Maryland's real property code, tenants may deposit their rents in an escrow account held by the district court when landlords fail to remove lead-based paint that is accessible to children.

- Both states provide some level of quality control over lead testers, abatement contractors, and abatement inspectors. Massachusetts requires training and licensing of abatement contractors and inspectors, and testing laboratories must be certified. Maryland requires that workers be trained in safe and appropriate abatement procedures (MDE, 1992) and has established a training program employing private and public training organizations that are certified by the state.

- Both states have loan or grant programs to provide abatement funds for property owners with limited resources. Massachusetts has also established a $1,000 tax credit for private property owners doing lead-based paint abatement. (A new bill that has passed the Massachusetts house would increase the tax credit to $2,500 (Carroll, 1993).)

- Both have attempted to provide relocation resources for families during abatement. However, the availability of suitable interim housing is a problem. The State of Maryland has given the City of Baltimore a grant for "lead-safe" houses to be used for transitional housing during abatement.

- Both states require that all cases of lead poisoning be reported to the state health department. Private physicians must screen all preschool children for lead poisoning and report cases of children with high blood lead levels to appropriate authorities for followup. In 1991, a year after Massachusetts passed its regulation requiring screening of all pre-school children, the screening rate of children aged 6 months to 6 years was 74% compared with 50% in 1989 (MDH, n.d.).

- Both states have legislation that calls for investigation, testing, and approval of new abatement or containment technologies. Maryland has been involved in ongoing research on the effects of lead dust on blood lead in abatement workers and the development of testing protocols for encapsulation products. Maryland has pioneered the development of standards and procedures for worker protection during abatement, dust containment, and post-abatement cleanup, inspections, and clearances. These methods have provided much of the basis for the National Institute of Building Science's guidelines for testing and abatement of lead-based paint in housing, which in turn, became the basis for the HUD interim guidelines (HUD, 1990).

Rhode Island was able to draw from features of the existing Massachusetts lead poisoning prevention and abatement program in addition to adding aspects of its own (Vanderslice, 1993). Rhode Island's Lead Poisoning Prevention Act was passed in 1991. Under the law, the Department of Health is authorized to expand blood lead screening to all children under six and set up a public education program. Houses where children with blood lead levels of 25 μg/dl or greater have been identified must be inspected, and nonintact lead hazards in these homes must be abated (RIDH, 1993). The Rhode Island program differs from the Massachusetts system by requiring comprehensive inspection of soil and exterior dust, whereas Massachusetts requirements include only inspection of interior dust and paint (RIDH, 1993). Rhode Island also generally requires less extensive clean-up (i.e., lead does not need to be removed if it is kept intact within the home) (R 23-24.6-PB; 105 CMR 460.020; 460.170). However, a new bill passed by the Massachusetts House would allow less expensive options for decreasing exposure to lead paint (Carroll, 1993).

Several other states have notable programs for reducing lead-based paint hazards. California initiated its activities in 1986 which included: screening of children in three geographical areas, establishing a program to reduce exposure, reporting high blood lead levels to the Department of Health Services, and submitting a policy report to the legislature on future lead poisoning prevention programs (Florini et al., 1990). Minnesota was one of three states (including Massachusetts and Maryland) to upgrade its lead paint abatement practices at a time when the standard practices had not been changed for 40 years (Farfel and Chisolm, 1990). Other states, including Missouri, Louisiana, Vermont and New Hampshire, are in the process of setting up childhood poisoning prevention programs (Farquhar, 1993).

Local Programs

Local lead-poisoning programs are similar to state programs in several organizational and programmatic features (HUD, 1990). For instance, programs are usually located in the health department. In addition, resources for carrying out local activities have been limited.

Differences between typical state schemes and selected city programs lie more in the extent than in the substance of the activities (HUD, 1990). In general, city programs are more focused and seem to receive higher priority, which may be due to the urgency of the lead-paint problem in larger cities.

In the *Comprehensive and Workable Plan for the Abatement of Lead-Based Paint in Privately Owned Housing* (HUD, 1990), the Department of Housing and Urban Development outlined several distinguishing features of local programs as determined by investigation of ten selected cities:

- A city that is governed both by local ordinances and state regulations for lead-poisoning prevention and detection activities usually has local laws that are more stringent than state laws and may supersede the state requirements.

- In addition to providing intervention after cases of lead poisoning have been detected, local programs may require intervention as a result of targeted inspection or tenant complaints. Several cities, including Baltimore, Chicago, Louisville, New York, and Philadelphia, are authorized to take such preventive measures.

- In general, the city programs show more cooperation and coordination between agencies.

- City programs usually screen for high blood lead levels more systematically and target high-risk areas for screening.

Under Title X, several cities and one county have recently received increased funding for lead abatement. These localities include Boston, Baltimore, Cleveland, and Alameda County in California (NCLSH, 1993). In addition, other recent funding, authorized by the 1986 amendments to Superfund, has been given to Boston, Cincinnati, and Baltimore to evaluate the impact of residential lead contaminated soil abatement on children's blood lead levels (Weitzman et al., 1991; Cook, 1993).

Of the childhood poisoning prevention programs on the local level, Baltimore has one of the most extensive schemes. As early as 1951, the city banned the use of lead paint in the interior of residences (Mushak and Crocetti, 1990). When a lead-poisoned child is identified, the health department must be notified and the housing unit is inspected (BCHD, 1993). When the city inspects a building and finds a lead-based paint hazard, a violation notice is issued to the property owner, who must abate the lead hazard (BCHD, 1993). Baltimore is currently running a pilot program allowing alternative abatement strategies (instead of complete removal of lead hazards) to make lead homes safe. These strategies involve stabilization of identified lead-based paint hazards, with complete replacement required only for windows and certain surfaces in poor condition. Dust samples are taken for two years after stabilization.

2.3.5 Benefits of Defining a Lead Standard for Paint, Dust, and Soil

Although several states and localities have taken action on lead-based paint, many have no standards for paint, dust, and soil abatement (nor standards for any one of the three media). In addition, of the states and local areas that do have standards, the level of paint, dust, and soil considered unacceptable differs among states. By providing definitions at the federal level for lead paint hazards and dangerous levels of lead in dust and soil, those states that do not have standards may be prompted to adopt standards more quickly. In addition, the federal guidelines will provide consistency between the states.

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3. PROBLEM DEFINITION AND REGULATORY OPTIONS

This chapter characterizes the lead contamination problem to be addressed under Section 403 and presents a rationale for government intervention. A risk summary, provided in the first part of this chapter, presents quantitative estimates of exposures, blood lead distributions, and incidences of adverse health effects. The second part of this chapter presents an evaluation of the market failure associated with these residential lead risks, the need for federal regulation, and a discussion of possible regulatory option.

3.1 RISK SUMMARY

This section describes the risk assessment modeling procedures, information sources, and assumptions used to estimate the incidence of adverse health effects to children resulting from exposure to lead present in paint, soil and dust in residential settings. This risk assessment model is used to support the Section 403 impact analysis by determining both the baseline incidence of health damages expected in the absence of actions induced by Section 403, and the benefits that will result from various exposure reduction actions that may result from the implementation of Section 403 rules.

The risk assessment model has three major components:

- Characterization of lead exposure from residential paint, soil and dust;
- Calculation of blood lead distributions resulting from these exposures; and
- Prediction of the incidence of adverse health effects from the blood lead distributions.

Each of these components of the risk assessment model is discussed later in this chapter. First, however, it is important to discuss some of the key underlying assumptions and premises for the risk assessment model.

In this analysis, it is recognized that the presence of lead in paint, soil and dust is a long-term environmental problem. Even though lead paint has not been used for residential purposes since 1979, and major historical sources of lead deposition to soil such as automotive emissions from leaded gasoline have been eliminated or severely curtailed, the existing stock of lead in paint, soil and dust from these past sources will remain a major source of exposure to children for many generations. Consequently, the risk assessment model has been constructed to address not only the exposure and health risks to those children currently living in lead-contaminated homes, but also the risks that children who are born into these homes over the next several decades will face if abatement actions are not taken.

To incorporate this consideration, the risk assessment model is built around the concept of annual cohorts of children being born into homes over a 50 year period, beginning in 1994. Based on Census Bureau population projections and other assumptions, the model incorporates estimates of the number of homes and births expected for each year of this time frame. It is convenient to view the modeling conceptually as involving an iterative, stepwise process where separate calculations are made of the incidence of adverse effects for each of these 50 annual cohorts of children, which are then summed to obtain the total for the full modeling period. Computationally, however, the modeling process involves instead a determination of the incidence of these adverse effects for the cohort of children born in first year the modeling time frame. This result is then "multiplied" using factors reflecting birth rates over the 50 year period and the changes in the housing stock characteristics to obtain the incidence for all children born over the full modeling time frame. Results for individual years are not, however, explicitly isolated.

Because of this modeling procedure, most of the Risk Summary discussion focuses on the first year of the model, which as noted above has been set at 1994. In Section 3.1.4, the derivation of the factors used to multiply the first year results to the full 50 year time frame are presented.

The terms "baseline" and "first model year" are used throughout this section. These are not synonymous terms. The term "baseline" refers to the analyses of exposure and incidence of adverse effects assuming there are no Section 403-induced changes. Subsequent analyses are performed in which it is assumed that different types of exposure reduction actions are induced by Section 403, and the results of these are then compared with this baseline. "First model year" simply refers to the results of either the baseline analysis or the alternative exposure assumption analyses for the first model year cohort. In all cases, these first model year impacts are computed, and those results are then extrapolated to the full 50 year modeling time frame through the use of multipliers, as noted previously.

It is important to note that the baseline analysis reflects an assumption that no specific abatement actions will be performed to reduce current and future exposure to lead from paint, soil, and dust in the absence of promulgated Section 403 regulations. As discussed later, the risk assessment model does include assumptions regarding the disappearance of older homes over time, which has the effect of reducing the probability that a child will be born into a home with lead paint in future years. However, in the baseline hazard assessment analysis, it is assumed that no abatements of lead paint, soil or dust will be performed in the absence of Section 403 regulations. This is obviously not the case, since many states and municipalities are currently implementing lead abatement programs. However, it is difficult to estimate how many such abatements will be done over the next several decades.

The "no abatement" assumption for the baseline clearly results in an overestimate of the damages expected in the absence of the Section 403 rule as well as the benefits of having the rule. Nevertheless, using the "no abatement" assumption in the baseline provides a common basis for comparing the effectiveness of alternative hazard levels, and it is not expected to affect the outcome of the analysis in terms of identifying the range of hazard levels that maximize net benefits.

3.1.1 Characterization of Exposure

The purpose of the exposure characterization component of the model is to define the distribution of lead levels in paint, soil, and dust in privately-owned housing stock in the US. The exposure assessment also addresses other characteristics of these homes that affect children's exposure, particularly the condition of the lead paint.

The distribution of current lead levels in paint, soil and dust in the US housing stock is derived from the results of the survey sponsored by the US Department of Housing and Urban Development. That survey was conducted in 1989-1990 to provide better estimates of the extent of lead paint hazards in the Nation's private housing stock. The results of that survey have been detailed by HUD in its December 1990 Report to Congress entitled *Comprehensive and Workable Plan for the Abatement of Lead-Based Paint in Privately Owned Housing* (HUD, 1991).

The HUD survey focused on privately-owned, occupied homes built prior to 1980. HUD estimated that at the time its survey was conducted, there were approximately 77 million pre-1980 homes in the US. The focus of the HUD survey on pre-1980 homes reflects the ban on the use of lead-based paint for residential purposes in 1978 by the Consumer Product Safety Commission acting under the authority of the Consumer Product Safety Act.

There were a total of 284 homes sampled in the HUD survey. The survey sample design involved a stratification of the pre-1980 housing stock into six groups reflecting three construction-period categories (pre-1940, 1940-1959, and 1960-1979) and two dwelling types (single family and multifamily). To adjust for disproportionate sampling within these six strata, as well as to correct for recognized disproportionate sampling with respect to census region and presence/absence of children under age 7, the 284 HUD samples were given "weights" by HUD so that the results from the 284 samples could be extrapolated to the national total of 77 million pre-1980 homes. These HUD-specified weights were used in the risk assessment modeling performed here, with additional adjustments made to them as described later to accommodate the post-1980 housing stock.

Lead measurements of interior and exterior paint, exterior soil, and interior dust were taken at each of the 284 HUD sample homes. Generally, measurements of lead in these media were made at several locations and surfaces in each sample home. Other information relevant to assessing exposure to lead in these homes was also obtained, such as the existence and extent of damaged surface area of paint. The following briefly describes how these HUD measurement data were used to characterize exposure potential in the model.

<u>Lead in Paint</u>. The most commonly used method to measure the level of lead on painted surfaces in homes is the XRF (x-ray fluorescence) technique, which measures lead in paint present on surfaces in units of mg/cm^2. It should be noted that because of

limitations in this analytical method, low levels of lead paint reported by XRF measurements (for example, in the range of approximately 1.0 mg/cm^2 or less) are considered much less reliable than are higher readings. For the purposes of this model, XRF readings of 0.7 mg/cm^2 were used as the cut-off to distinguish between homes with and without lead based paint. That is, homes having reported XRF measurements of 0.6 mg/cm^2 or lower were considered to be free of lead paint.

Exposure to lead paint in the risk assessment model is associated primarily with interior lead paint levels. In the HUD survey, interior XRF readings were taken at several locations in each home, including one randomly selected wet room (i.e., rooms having plumbing such as a kitchen or bathroom) and one randomly selected dry room. Measurements were made on several substrates within those rooms, such as walls, ceilings, windows, molding, door systems, and shelves. The value used to characterize paint exposure potential in homes was the maximum interior XRF value, which is the most frequently used measure to characterize lead paint levels in homes.

Data were also obtained on the XRF value for exterior paint. This information was used in the model mainly in the abatement cost analysis to identify those homes undertaking soil abatement that would also require exterior paint abatement to be fully effective. Exterior lead paint information was also used in conjunction with the interior paint reading to identify the number of lead-free homes in the HUD sample. As discussed later, this information was needed to adjust the weighting factors to simulate changes in future characteristics of the housing stock.

The HUD survey also provided information on the condition of the lead paint in these homes. For the purposes of this model, housing units reported to have more than 5 ft^2 of damaged interior lead paint were classified as "bad condition" homes, as discussed further below.

<u>Lead in Soil</u>. In the HUD survey, residential soil readings were taken near the entrance to the home, at the drip line, and at a remote location. Soil lead measurements were reported in parts per million (ppm). To be most representative of the overall levels to which children are exposed, the arithmetic average of the individual soil lead levels measurements was used to characterize each home.

The definition of lead-contaminated soil under Section 401 of TSCA Title IV refers specifically to "bare soil on residential real property that contains lead at or in excess of the levels determined to be hazardous" by EPA under the section 403 regulations.

It has been noted that exposure of children to lead from soil is enhanced when they play on nongrassy surfaces rather than on grass-covered areas (Madhavan et al., 1989; Lewis and Clark County Health Department et al., 1986). It has been suggested that contact with bare soil areas may result in increased ingestion of soil particles by children. Also, bare soils may contribute more to household dust than covered soils. While the enhancement of lead exposure from bare soils is often noted in the technical literature, no studies were found that specifically addressed a quantitative difference in children's blood lead levels as a function of the degree of soil cover. Most studies concerning the relationships between soil lead and blood lead levels do not note the condition of the soil with respect to grass or other form of cover.

In the risk analysis and benefit-cost modeling that has been performed for this impact assessment, it has not been possible to specifically isolate and focus on lead hazards associated with <u>bare</u> residential soils separately from other residential soils that are partially or completely covered with grass or some other form of ground cover.

One major impediment is that the data in the HUD survey (which provides the basis for the national estimates of the distribution of lead levels in residential soils used in the modeling performed here) does not include any indication as to the condition of the soils in the sample homes. Consequently, we cannot stratify the HUD-measured levels of lead in the soils of the US privately-owned housing stock in terms of the condition of the soil as bare or covered. No information from other sources concerning the national incidence of lead levels as a function bare or covered soil in residential settings is known to be available. Therefore, we are unable to estimate either the number of homes that have bare soil, or the distribution of lead levels in bare soils and covered soils.

A second impediment is that in the IEUBK model there is no differentiation made between bare and covered soil in estimating intakes. That is, lead intake via soil is addressed in the IEUBK model in terms of a daily ingestion of soil. (This is assumed to be 45% of the combined daily soil and dust intake which ranges from 85 to 135 mg/day depending upon age.) The model does not suggest different default values either for the soil fraction value or for the total ingestion amount of soil and dust as a function of prevailing soil conditions. However, it seems reasonable to assume that for a given lead concentration in soil, lead intake (and therefore blood lead levels) would be greater for children regularly exposed to bare soils than for children exposed to soils that have some form of cover. Though not stated explicitly, it appears that the assumed intake values in the IEUBK model reflect an averaging of a range of intakes that may include contact with both bare and covered soils.

In terms of the aggregate, baseline risk assessment, the inability to specifically address bare and covered soils may result in an "averaging out" of the overall health damages by overestimating damages for children exposed to a given lead level in covered soils while underestimating damages for other children exposed to similar lead levels in bare soils. The potential effects of this averaging out on the benefit and benefit-cost implications of setting a soil hazard level is discussed further in Chapters 5 and 7.

<u>**Lead in Dust**</u>. In the HUD survey, floor dust lead concentrations (in ppm) were obtained for a wet room, dry room, and at the entry way. An arithmetic mean of these measurements was used to characterize the floor dust concentration for each HUD

home. Dust lead measurements were also taken for window wells and window sills, but were not used in the averaging. Dust loading measurements, reported in units of ug/ft^2, were also taken in the HUD study. However, the model for predicting blood lead levels from exposure to dust (as described in the next section) requires dust concentrations, and cannot use dust loading values directly.

For the purposes of the risk assessment model, each of the 284 HUD sample homes represents a group or category of homes. The lead paint, soil, and dust characteristics for every home in each of these groups is given by the measured values in the corresponding HUD sample home.

The number of homes in each category is given by the weighting factor applied to the HUD sample which, as described previously, accounts for several sampling strata characteristics. The sum of the HUD weights is approximately 77 million homes, which is the estimated current size of the privately-owned housing stock built prior to 1980. As described in Section 3.1.4, below, it is estimated that the total privately-owned housing stock in 1994 (the year that is used as the starting point for the risk assessment modeling) is approximately 96 million. This implies that approximately 19 million homes were built from 1980 through 1994 in addition to the 77 million built prior to 1980. Unfortunately, there is no comparable survey providing useful lead paint, soil, and dust measurement data for the homes built from 1980 to the present. To incorporate post-1980 homes into the model, the two assumptions were used.

First, it was assumed that these homes will be free of both interior and exterior lead-based paint. Second, it was assumed that soil and dust lead levels in post-1980 homes will follow a pattern similar to soil and dust lead levels in pre-1980 sample homes that are also free of lead paint. Accordingly, the weights of the subset of pre-1980 homes in the HUD survey that were found to be free of both interior and exterior lead-based paint were adjusted upward (proportionately) to account for the additional post-1980 homes such that the sum of all of the weights totaled 96 million.

Exhibits 3-1, 3-2, and 3-3 summarize the resulting distribution of 1994 homes by paint, soil and dust lead levels, respectively. These distributions reflect the data obtained for the 284 HUD homes and the adjusted HUD weighting factors to extrapolate from those 284 samples to the 96 million occupied, privately-owned homes estimated for 1994.

The data shown in Exhibit 3-1 indicate the pervasiveness of lead paint in homes despite the ban on its use in 1979. Over 40% of homes, some 40 million, are still expected to have interior lead paint present in 1994. While the majority of these have maximum interior XRF values in the low end of the range (1 to 6 mg/cm^2), there is still a substantial number of homes with lead paint present at very high XRF levels. For example, there are about 3.8 million homes estimated to have lead based-paint present with a maximum interior XRF value at or above 10 mg/cm^2.

The distribution of soil lead levels shown in Exhibit 3-2 indicates that just over half of all homes have average soil lead levels below 100 ppm. About 13% of homes have soil lead levels at or above 500 ppm, and only 1.6% are estimated to have lead levels above 3,000 ppm. The maximum average value observed from the HUD survey was 8,800 ppm, affecting just over 200,000 homes.

Relative to soil lead levels, there is a much higher frequency of dust levels above 100 ppm (over 96%) as well as a higher incidence in the middle range of values, with some 36% exceeding 500 and about 15% exceeding 1,000 ppm. The maximum dust lead concentration found was 5,900 ppm.

Exhibit 3-1

Summary of Distribution of Maximum Interior XRF Values for 1994 Homes

Maximum Interior XRF Measurement	Estimated Number and Percent of 1994 Homes		Cumulative Number and Percent of 1994 Homes	
22	174,136	0.18%	174,136	0.18%
20	1,308,115	1.36%	1,482,250	1.54%
13	116,914	0.12%	1,599,164	1.66%
12	233,828	0.24%	1,832,992	1.90%
11	334,584	0.35%	2,167,576	2.25%
10	1,596,469	1.66%	3,764,045	3.90%
9	1,453,400	1.51%	5,217,445	5.41%
8	679,926	0.71%	5,897,371	6.12%
7	717,116	0.74%	6,614,486	6.86%
6	1,735,126	1.80%	8,349,612	8.66%
5	646,947	0.67%	8,996,559	9.34%
4	634,211	0.66%	9,630,771	9.99%
3	2,881,551	2.99%	12,512,322	12.99%
2	4,902,934	5.09%	17,415,256	18.08%
1	21,242,577	22.05%	38,657,833	40.13%
0	57,675,167	59.87%	96,333,000	100.00%

Exhibit 3-2

Summary of Distribution of Average Soil Concentrations for 1994 Homes

Average Soil Concentration (ppm)	Estimated Number and Percent of 1994 Homes		Cumulative Number and Percent of 1994 Homes	
8800	217,940	0.23%	217,940	0.23%
5800	120,342	0.12%	338,282	0.35%
3100	811,603	0.84%	1,149,884	1.19%
3000	420,357	0.44%	1,570,241	1.63%
2300	1,376,717	1.43%	2,946,959	3.06%
2200	300,785	0.31%	3,247,744	3.37%
1700	108,201	0.11%	3,355,945	3.48%
1500	193,020	0.20%	3,548,965	3.68%
1400	116,914	0.12%	3,665,879	3.81%
1300	811,602	0.84%	4,477,480	4.65%
1200	116,644	0.12%	4,594,124	4.77%
1100	127,818	0.13%	4,721,942	4.90%
1000	2,516,509	2.61%	7,238,451	7.51%
800	885,948	0.92%	8,124,399	8.43%
700	373,906	0.39%	8,498,305	8.82%
600	941,777	0.98%	9,440,082	9.80%
500	2,960,312	3.07%	12,400,393	12.87%
400	1,594,968	1.66%	13,995,361	14.53%
300	3,887,101	4.04%	17,882,463	18.56%
200	6,292,020	6.53%	24,174,483	25.09%
100	22,015,661	22.85%	46,190,144	47.95%
0	50,142,856	52.05%	96,333,000	100.00%

Exhibit 3-3

Summary of Distribution of Average Floor Dust Concentrations for 1994 Homes

Average Dust Concentration (ppm)	Estimated Number and Percent of 1994 Homes		Cumulative Number and Percent of 1994 Homes	
5900	1,197,765	1.24%	1,197,765	1.24%
5800	120,342	0.12%	1,318,106	1.37%
5300	532,215	0.55%	1,850,321	1.92%
4400	369,692	0.38%	2,220,013	2.30%
3600	127,818	0.13%	2,347,831	2.44%
3300	859,142	0.89%	3,206,972	3.33%
3200	256,992	0.27%	3,463,964	3.60%
2700	748,083	0.78%	4,212,047	4.37%
2500	233,557	0.24%	4,445,604	4.61%
2400	116,644	0.12%	4,562,248	4.74%
2100	393,074	0.41%	4,955,322	5.14%
1800	100,535	0.10%	5,055,858	5.25%
1700	925,289	0.96%	5,981,147	6.21%
1600	295,510	0.31%	6,276,657	6.52%
1500	402,265	0.42%	6,678,921	6.93%
1400	1,042,945	1.08%	7,721,866	8.02%
1300	787,851	0.82%	8,509,717	8.83%
1200	2,819,209	2.93%	11,328,925	11.76%
1100	474,932	0.49%	11,803,858	12.25%
1000	2,141,279	2.22%	13,945,137	14.48%
900	1,041,672	1.08%	14,986,809	15.56%
800	3,294,547	3.42%	18,281,356	18.98%
700	2,043,610	2.12%	20,324,966	21.10%
600	7,006,259	7.27%	27,331,225	28.37%
500	7,654,178	7.95%	34,985,402	36.32%
400	6,940,566	7.20%	41,925,968	43.52%
300	12,572,751	13.05%	54,498,719	56.57%
200	18,270,537	18.97%	72,769,257	75.54%
100	20,140,532	20.91%	92,909,788	96.45%
0	3,423,212	3.55%	96,333,000	100.00%

To carry out the risk assessment modeling, some additional stratification of the 284 categories of homes was also performed to reflect characteristics that affect exposure from interior lead paint in these homes. Of the 284 HUD samples, 141 were found to have some lead paint present (i.e., maximum interior XRF values of 0.7 mg/cm^2 or more). Each of the 141 groups of homes represented by these samples were divided into eight subgroups. Note that the lead paint, soil and dust levels in each of these subgroups remain the same as in the original group from which each is derived. The eight subgroups were created using the following three characteristics:

- Based on data presented in the HUD report two subcategories were created to differentiate between homes having interior lead paint on windows (40%) and those that do not (60%).

- Using HUD data, homes with lead paint were differentiated between those having lead paint in bad condition (24%) and good condition (76%). The criteria used for bad condition paint was that provided by HUD in its report as homes having more than 5 ft^2 of damaged, painted surface area.

- Lastly, 25% of all homes were identified as ones in which a child would exhibit pica, while children in the remaining 75% of homes would not have pica. (This and other pica assumptions are discussed in Section 3.1.2.)

These percentages were applied to the weights for each HUD home having interior paint to obtain new weights for each of the eight subgroups.[1] For example, if one of the original 141 HUD samples with lead paint had a weight of 10,000 (i.e., it represents 10,000 of the 96 million homes in 1994), the eight subgroups created from it would be weighted as follows:

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1 An alternative approach was considered for incorporating the windows and paint condition characteristics into the modeling. This was to simply consider these characteristics in an "all or none" manner for the homes represented by each of the 284 HUD samples. For example, the national estimate of homes with paint in bad condition could have been taken as the sum of the weights for each of the 284 HUD sample homes found to have paint in bad condition. This would have implied that only those homes with those particular combinations of lead paint, soil and dust levels have lead paint in bad condition, while homes with all other combinations of levels have interior paint in good condition. Similarly, homes with lead paint on windows would have been restricted in the model to only those homes with the particular paint, soil and dust lead combinations in the representative HUD sample homes where lead paint on interior windows was observed. Given the relatively small size of the HUD sample homes, it was judged that this "all or none" approach would be less representative of the prevalence of these conditions across all combinations of lead levels in paint, soil and dust in homes. Therefore, the approach used here was to apply the frequency observed (weighted by the HUD sample weights) for these characteristics across all homes with interior lead paint.

Subgroup Characterisics	Weight	Derivation
Lead paint on windows, good condition, no pica:	2,280	(= 0.4 * 0.76 * 0.75 * 10,000)
Lead paint on windows, bad condition, no pica:	720	(= 0.4 * 0.24 * 0.75 * 10,000)
Lead paint on windows, good condition, pica:	760	(= 0.4 * 0.76 * 0.25 * 10,000)
Lead paint on windows, bad condition, pica:	240	(= 0.4 * 0.24 * 0.25 * 10,000)
No lead paint on windows, good condition, no pica:	3,420	(= 0.6 * 0.76 * 0.75 * 10,000)
No lead paint on windows, bad condition, no pica:	1,080	(= 0.6 * 0.24 * 0.75 * 10,000)
No lead paint on windows, good condition, pica:	1,140	(= 0.6 * 0.76 * 0.25 * 10,000)
No lead paint on windows, bad condition, pica:	360	(= 0.6 * 0.24 * 0.25 * 10,000)

The presence or absence of lead paint on windows was used primarily in the benefits analysis to differentiate between homes needing full paint abatement (those without lead on windows) and those that could be abated by replacing the windows only.

The homes having the combination of both lead paint in bad condition and pica children are particularly important for the risk analysis. For these children, the model used to predict blood lead levels (described in Section 3.1.2) included special input assumptions for paint chip ingestion, as well as for exposure through dust and soil ingestion.

The 143 groups of homes without interior lead paint were not further stratified in the model. As a result of these assumptions, the US privately-owned housing stock was ultimately stratified into a total of 1,271 subgroups. Of the original 284 categories based on the HUD samples, 141 had interior lead paint, which were therefore stratified into 1,128 subgroups (8 x 141). Adding to these the 143 that did not have interior paint results in the total of 1,271.

Having the housing stock fully stratified and properly weighted to account for the 96 million homes in 1994, the model then applied the estimated probability of a child being born into any home of 0.03994 for 1994 to determine the number of homes in each strata expected to have a child in the first model year (see Section 3.1.4 for additional discussion of birth rates). Blood lead distributions, and the incidence of adverse health effects, were then computed for the children born into each of the 1,271 categories of homes.

3.1.2 Determining Blood Lead Distributions

For each of the 1,271 categories of homes created in the model, an estimate was made of the geometric mean blood lead for the children born into them, all of whom are assumed to live in those homes from birth through age seven. The geometric mean blood lead estimates were obtained using EPA's Integrated Exposure, Uptake and Biokinetic Model for lead, hereafter referred to as the IEUBK model.

The IEUBK model has been developed by EPA to use as a tool for estimating the geometric mean blood lead levels in populations of children exposed to various levels of lead in environmental media. The IEUBK model has been under development for several years, and has been available in several interim versions. The version of the IEUBK model used for this analysis became available in July 1993, and is currently undergoing validation studies.

The IEUBK model is designed to use data on lead concentrations in air, water, soil, household dust, diet, and paint chips to estimate the geometric mean (GM) blood leads for a population of children exposed to those specified environmental concentrations. To account for individual variability within that population of children exposed to similar environmental levels, it is assumed that the overall distribution of blood lead levels for that population is lognormal, with an assumption made for the geometric standard deviation (GSD) of that distribution, as discussed further below.

Exhibit 3-4 summarizes the IEUBK input assumptions used for this analysis. Shown there are assumptions regarding levels of lead in each medium, daily intake of those media, and absorption of lead from each source. The levels of lead in air and water, and the dietary intake values are kept constant for all children, using the values shown in the Exhibit 3-4. The input values for soil and dust are those in each housing group obtained from the HUD data as described above. The intake of lead for the subgroup of children assumed to be ingesting lead paint chips was estimated as follows.

An estimate was provided by Elias (1993) that children ingesting paint chips ingest an average of 2.5 chips per week, each 1 cm^2. It was also assumed that these chips are 0.1 mm thick, resulting in an overall size of 0.01 cm^3. It was also assumed that the density of a lead paint chip is 2 g/cm^3, a typical value for solid materials.

A draft IEUBK guidance manual (EPA, 1991) provided a relationship for estimating the lead concentration in a paint chip from the XRF measurement, which as noted previously has the units of mg/cm^2. This relationship is:

$$\frac{10{,}000\ \mu g_{Pb}}{1\ g_{Paint}} \text{ per XRF } (mg/cm^2) \qquad \text{Equation 3.1}$$

Therefore, a paint chip from a lead-painted surface having an XRF measurement of 10 would be estimated to have 100,000 µg of lead (or, 0.1 g of lead) per gram of paint chip.

Combining the above assumptions provides an estimate of the daily intake of lead from paint chip ingestion as a function of the XRF value:

$$\left(\frac{10{,}000\ \mu g_{Pb}}{1\ g_{paint}} \text{ per XRF}\right) \bullet \left(\frac{2\,g_{paint}}{cm^3{}_{chip}}\right) \bullet \left(0.01\,cm^3{}_{chip}\right) \bullet \left(\frac{2.5\,\text{chips}}{\text{week}}\right) \bullet \left(\frac{1\,\text{week}}{7\,\text{days}}\right)$$

Equation 3.2

$$\cong \frac{70\,\mu g_{Pb}}{\text{day}} \text{ per XRF}$$

Therefore, a child ingesting paint chips in a home where the interior XRF value is 10 mg/cm^2 is assumed to have an intake of 700 ug/day from this source.

Exhibit 3-4

Summary of Parameter Values Used in IEUBK Model

Air Parameters: All air parameters use default values

Vary air concentration by year?	No
Outdoor air lead concentration (ug/m3):	0.10
Indoor air concentration (% of outdoor value):	30%

Diet Intake Parameters: Diet parameters were reduced to 50% of default values.

Age:	0-1	1-2	2-3	3-4	4-5	5-6	6-7
Diet Intake (ug/day):	2.75	2.89	3.25	3.12	3.01	3.17	3.5

Water Intake Parameters: All water parameters use default values

Lead concentration in water: 4 ug/L

Age:	0-1	1-2	2-3	3-4	4-5	5-6	6-7
Drinking water consumption (L/day):	0.02	0.05	0.52	0.53	0.55	0.58	0.59

Soil and Dust Intake Parameters: Soil and dust levels are input. All other parameters use default values.

Soil/dust ingestion weighting factor: 45% soil : 55% dust

Age:	0-1	1-2	2-3	3-4	4-5	5-6	6-7
Total soil + dust intake (g/day):	0.085	0.135	0.135	0.135	0.1	0.09	0.085

Absorption method values: (* Indicates change from default)

	Total Absorption (percent)	Fraction of Total Assumed Passive Absorption
Soil	0.3	0.05 *
Dust	0.3	0.05 *
Water	0.5	0.05 *
Diet	0.5	0.05 *
Alternate	0.1	0.05 *

As indicated in the previous section, homes with lead paint were stratified to isolate the subset having children ingesting lead paint chips. It was estimated from the HUD data on paint condition that 24% of homes with interior lead paint have non-intact paint. It was also assumed that 25% of children exhibit pica. This estimate was based on Baltrop (1966) as cited in HUD (1991) that the frequency of pica among children in inner cities is 20-30%. A lower estimate of pica incidence has been provided by Mahaffey (1993) based on an analysis of NHANES II data indicating that the incidence of pica among children 0.5-3 years old is 11%. This lower estimate became available late in the modeling process. Incorporating it will, of course, reduce the computed effect of paint chip ingestion on blood lead levels. Since there is a concern that this may already be underestimated in the model, as discussed in Section 3.1.5 below, it was decided not to include this lower pica frequency estimate at this stage. However, it may be included in a subsequent sensitivity analysis.

The combined conditions of non-intact paint and pica children therefore implies an overall estimate that 6% (i.e., 25% of 24%) of children in homes with interior lead paint will ingest lead paint chips.

It is important to note that for children in the remaining 94% of homes, the blood lead geometric means estimated from the IEUBK model are not affected either by lead paint XRF value or by the condition of the paint in those children's homes. That is, pica and non-pica children born into homes having paint in good condition have no difference in their calculated blood lead levels, all other exposure conditions being equal. Similarly, non-pica children in homes with lead paint in bad condition have the same calculated blood lead as those with lead paint in good condition, all other exposure conditions being the same. Exhibit 3-5 shows the predicted blood lead levels from the IEUBK model for these various combinations of pica and condition for a given set of paint, soil and dust lead levels.

Exhibit 3-5

Comparison of Predicted Blood Lead Levels for Pica/Non-Pica Children in Homes with Lead Paint in Bad or Good Condition

	Pica Children	Non-pica Children
Lead Paint in Bad Condition	13.89 ug/dl	6.93 ug/dl
Lead Paint in Good Condition	6.93 ug/dl	6.93 ug/dl
Assumed exposure conditions:	Interior XRF = 5 mg/cm^2 Soil = 500 ppm Dust = 500 ppm	

Exhibit 3-6 provides a summary of predicted geometric mean blood leads for soil and dust lead concentration combinations ranging between 100 and 1,000 ppm each. These estimates, which exclude any contribution from paint chip ingestion, indicate that the geometric means increase by about 0.5 ug/dl (ranging from about 0.35 to 0.70 ug/dl) for each increase of 100 ppm in either soil or dust. For example, at a soil level of 500 ppm and dust level of 100 ppm, the estimated geometric mean is 4.55 ug/dl. At this same soil level, with dust increased to 200 ppm, the geometric mean blood lead increases to 5.18 ug/dl, a change of 0.63 ug/dl. The magnitude of the blood lead changes per 100 ppm of either soil or dust becomes lower as the soil and/or dust level becomes higher.

Exhibit 3-7 shows the impact of paint chip ingestion on predicted geometric means. For a given soil and dust concentration, the geometric mean of children ingesting paint chips is estimated to generally increase about 1 to 2 ug/dl per unit change in the XRF measurement, with the amount of increase less at high soil/dust/XRF combinations than at lower values.

Exhibit 3-6
Estimated Blood Lead Geometric Means (ug/dl) for Various Soil-Dust Combinations (excluding paint chip ingestion)

	Soil Concentration (ppm)									
Dust Conc. (ppm)	100	200	300	400	500	600	700	800	900	1000
100	2.33	2.91	3.47	4.02	4.55	5.06	5.56	6.05	6.52	6.98
200	3.04	3.60	4.14	4.67	5.18	5.67	6.16	6.63	7.08	7.53
300	3.72	4.26	4.78	5.29	5.78	6.26	6.73	7.18	7.63	8.06
400	4.37	4.89	5.40	5.89	6.37	6.83	7.28	7.72	8.15	8.57
500	5.01	5.51	6.00	6.47	6.93	7.38	7.82	8.25	8.66	9.06
600	5.62	6.10	6.58	7.03	7.48	7.91	8.34	8.75	9.15	9.55
700	6.21	6.68	7.13	7.58	8.01	8.43	8.84	9.24	9.63	10.01
800	6.78	7.23	7.67	8.10	8.52	8.93	9.33	9.72	10.10	10.47
900	7.33	7.77	8.20	8.61	9.02	9.42	9.80	10.18	10.55	10.91
1000	7.87	8.29	8.71	9.11	9.50	9.89	10.26	10.63	10.98	11.33

Exhibit 3-7

Estimated Geometric Means (ug/dl) for Children Ingesting Paint Chips with Indicated XRF/Soil/Dust Levels

	Soil (ppm):	100	500	1000
	Dust (ppm):	100	500	1000
XRF:	0	2.33	6.93	11.33
	1	4.47	8.60	12.60
	2	6.38	10.10	13.77
	3	8.09	11.48	14.85
	4	9.64	12.73	15.86
	5	11.06	13.89	16.79
	6	12.35	14.96	17.66
	7	13.54	15.96	18.48
	8	14.64	16.89	19.28
	9	15.65	17.75	19.97
	10	16.60	18.56	20.65

The IEUBK model provides age-specific estimates of the geometric mean blood lead for given exposure conditions at ages ranging from birth through seven years. For this analysis, the blood lead geometric mean predicted for age three was selected to use for estimating health damages. This age was selected because blood lead levels tend to peak at this age. It is also consistent with assumptions that cognitive effects are expected to occur only after having elevated blood lead levels for a period of 3 to 4 years.

As noted previously, the IEUBK model produces an estimate of the geometric mean for an assumed lognormal distribution of blood lead levels for the population of children exposed to similar environmental levels of lead. In this risk analysis, geometric mean estimates are made for 1,271 separate populations of children based on the stratification of homes as described in Section 3.1.1.

The variability of blood lead levels within in each of these 1,271 populations is estimated by using a standard assumption that the geometric standard deviation (GSD) is 1.6, regardless of the predicted geometric mean or the specific characteristics of the house where those children are born. The assumption that the GSD is 1.6 for all subpopulations, provided by Schwartz (1993a), is the best preliminary estimate of the overall population blood lead distribution GSD obtained from the recent NHANES III study. As discussed further below, this assumption that the overall population variance also applies uniformly to each subgroup within that population results in an inconsistent outcome. That is, by assuming that the GSD is 1.6 for each of the 1,271 subgroups, and then aggregating those 1,271 blood lead distributions to arrive at an overall population blood lead distribution, the resulting GSD for this overall population distribution is necessarily larger than the 1.6 value used for each subgroup. This effect will be discussed more fully in Section 3.1.5.

3.1.3 Estimated Incidence of Adverse Health Effects

The estimates of the incidence of adverse health effects resulting from exposure to lead in residential paint, soil and dust were derived primarily from the blood lead distributions obtained for each of the 1,271 categories of homes. The methodology used to obtain these estimates is essentially identical to the methodology that has been used previously for estimating the baseline health effects and benefits for regulating lead levels in gasoline and drinking water.

There are several categories of adverse health effects that have been associated with environmental exposure to lead. These include:

Adults:

- Hypertension
- Non-fatal heart attack and non-fatal stroke
- Premature death from all causes
- Possible cancer
- Reproductive effects (women only)

Infants and Children:

- Neonatal morality
- Cognitive effects, including reduced intelligence
- Interference with growth
- Interference with nervous system development
- Metabolic effects, impaired heme synthesis, anemia
- Possible cancer

In this analysis, only effects on children have been considered. Inadequate data are available to fully quantify the relationships between levels of lead in residential paint, soil and dust and adult blood lead levels.

The adverse health effects included for children in this risk analysis are the effects on intelligence and neonatal mortality. Specifically, the effects on intelligence included in the analysis are:

- IQ point decrements
- Incidence of IQ < 70
- Low level cognitive damage, estimated from the incidence of blood lead levels > 25 ug/dl.

The incidence of each of these adverse effects was estimated separately for the annual cohort of children in each of the 1,271 housing groups, with the total for all children in that year's cohort obtained by summing across all subgroups. Again, the blood lead distribution for each of these 1,271 subgroups were defined by the GMs obtained from the IEUBK model and the assumed GSD of 1.6.

As discussed further below, the estimates of the incidence of neonatal mortality do not directly involve the use of the blood lead distributions obtained from the IEUBK model.

<u>IQ Point Decrements</u>. The estimate of IQ point losses was obtained using a dose-response relationship of 0.25 points lost per ug/dl of blood lead, as provided by Schwartz (1993b). To obtain the total number of IQ points lost in a population of children, the 0.25 points lost per ug/dl change in blood lead is multiplied by the average blood lead level for that population. Note that the value obtained from the IEUBK model is the geometric mean for that distribution, not the arithmetic mean. To adjust for this, the relationship between the expected value and the geometric mean of a lognormal distribution was used:

$$E(X) = \exp\left[\ln(GM) + \frac{(\ln(GSD))^2}{2}\right] \quad \text{Equation 3.3}$$

where E(X) is the expected value (mean) of the distribution, GM is the geometric mean, and GSD is the geometric standard deviation. Taking the log of both sides gives:

$$\ln(E(X)) = \ln(GM) + \frac{(\ln(GSD))^2}{2} \quad \text{Equation 3.4}$$

Rearranging and exponentiating gives the ratio between the mean and the GM of:

$$\ln(E(X)) - \ln(GM) = \frac{(\ln(GSD))^2}{2} \quad \text{Equation 3.5}$$

$$\ln\left[\frac{E(X)}{GM}\right] = \frac{(\ln(GSD))^2}{2} \quad \text{Equation 3.6}$$

$$\frac{E(X)}{GM} = \exp\left[\frac{(\ln(GSD))^2}{2}\right]$$ Equation 3.7

For a GSD of 1.6, the resulting ratio between E(X) and GM is 1.117:

$$\frac{E(X)}{GM} = \exp\left[\frac{(\ln(1.6))^2}{2}\right]$$

Equation 3.8

$$= \exp\left[\frac{(0.47)^2}{2}\right] = \exp\left[\frac{0.221}{2}\right] = \exp[0.111] = 1.117$$

Therefore, the total lost IQ points for each group was estimated as:

$$GM \bullet 1.117 \bullet 0.25 \bullet (Pop)_k$$ Equation 3.9

where $(Pop)_k$ is the number of children in the kth group of homes. Thus if a group of homes has 10,000 children and an estimated GM from the IEUBK model of 4 ug/dl, the estimated IQ points lost among these children due to lead is 11,170.

Incidence of IQ < 70. The estimated incidence of IQ values below 70 was derived using the blood lead distributions for each housing strata in a manner similar to that above. In this case, however, the dose-response function is not constant across all blood lead values as in the case of IQ point losses. Rather, a piece wise linear function is used to relate the probability of IQ <70 to blood lead as shown in Exhibit 3-8.

Using the data shown in Exhibit 3-8, standardized estimates are first made of the expected incidence of IQ < 70 per unit population for blood lead distributions having GMs ranging from 0.5 up to 50 ug/dl (in 0.5 ug/dl increments), each with a constant GSD of 1.6. For a given housing group with a particular GM predicted from the IEUBK, the incidence of IQ < 70 is calculated simply as the unit value of IQ <70 obtained from the standardized estimates for a distribution with that GM, multiplied by the number of children associated with that housing group.

Exhibit 3.8

Elements of Piecewise Linear Function for Estimating Probability of IQ < 70 as a Function of Blood Lead (PbB) Range

PbB Range (ug/dl)	Slope	Intercept
0 - 5.0	2.04×10^{-4}	3.60×10^{-3}
5.1 - 7.5	4.88×10^{-4}	2.18×10^{-3}
7.6 - 10.0	1.068×10^{-3}	-2.17×10^{-3}
10.1 - 12.5	1.044×10^{-3}	-1.93×10^{-3}
12.6 - 15.0	9.76×10^{-4}	-1.08×10^{-3}
15.1 - 17.5	1.26×10^{-3}	-5.34×10^{-3}
17.6 - 22.5	1.328×10^{-3}	-6.53×10^{-3}
22.6 - 25.0	1.532×10^{-3}	-1.112×10^{-2}
> 25.0	1.464×10^{-3}	-9.42×10^{-3}

Blood Lead Levels > 25 ug/dl. The estimate of children having blood lead levels above 25 ug/dl, which is used as a surrogate indicator of the need for compensatory education due to low-level cognitive damage, is derived directly from the blood lead distributions for each strata using the normal distribution function with the estimated geometric mean obtained from the IEUBK model and the assumed geometric standard deviation of 1.6. The probability of exceeding 25 ug/dl obtained from the normal distribution function for a given subgroup of homes is then applied to the total number of children in that subgroup.

Neonatal Mortality. The estimation of the incidence of neonatal mortality was arrived at differently from the cognitive damages estimates described above. The neonatal mortality estimate is based on an approach provided in the CDC (1991) report. The CDC report used the following assumptions, which were also adopted here:

- The risk of infant mortality is 0.0001 per ug/dl of maternal blood lead. This is based on relationships between maternal blood lead and gestational age, and between gestational age and infant mortality as provided by Dietrich et al. (1987).

- The presence of lead paint in a home corresponds with a 2.13 ug/dl increase in maternal blood lead. This value is used in the CDC report, attributed to Bornschein (personal communication).

The calculation of the incidence of neonatal mortality is therefore limited to those homes that have interior lead paint. No distinctions were made between paint in good condition or bad condition, or between XRF levels. The birth rate for the first year cohort (0.03994 births/house, see Section 3.1.4) was used to estimate the number of pregnant women in each housing group for that year. Therefore, in the first model year, a housing group with lead paint having a weighting factor of 100,000 units would have an estimated 0.85 additional cases of neonatal mortality relative to a comparable size group with homes not having lead paint. This results from:

100,000 houses • 0.03994 births/house • 2.13 ug/dl • 0.0001 additional deaths per ug/dl

= 0.85 additional deaths   Equation 3.10

3.1.4 Extrapolation of First Model Year Results to Full Modeling Time frame

As discussed previously, the risk assessment modeling was premised on the assumption that presence of lead in paint, soil and dust in homes in the private housing stock will continue to affect children born into those homes over many decades. In the preceding sections, the description of the modeling methodology used to estimate the incidence of adverse health effects resulting from lead in paint, soil and dust focused on a single year's cohort, specifically that of the first year model year, i.e., 1994.

To carry out the modeling over the 50 year time frame of 1994 to 2043, it was first necessary to estimate both the size of the housing stock for each model year and the number of new children entering into that housing stock. Obtaining estimates of new children for this time frame was relatively straightforward. The Bureau of Census has published a document entitled *Population Projections of the United States by Age, Sex, Race and Hispanic Origin: 1992 to 2050* (Bureau of Census, 1992a). The estimated number of children under 1 year of age was used as the estimate of new children for each year.

Obtaining estimates of the total housing stock for each year was less straightforward since there was no published projection of housing levels found for the modeling time frame comparable to the population projections data noted above. Data were available from the 1992 *Statistical Abstract of the United States* (Bureau of Census, 1992a) and the *Forecast of Housing Activity* (NAHB, 1992) that provided estimates through the year 2000. To estimate the number of homes from 2000 through 2043, a series of analyses were performed on historical and projected data comparing number of persons in various age groups per household from 1960 to 2000 to find the best indicator to use for the 2000 to 2043 projections. Of the several approaches compared (specifically, using adults per household of ages 18+, 21+, 25+ and 18-64), the best predictor was found to be a ratio of 1.85 adults 21+ years old per household for the period 1980-2000.

Using that ratio with the population projections through 2050 for adults 21 and over from the sources noted above, the estimate of the total occupied housing stock for each year through 2050 was obtained. An adjustment was also made to eliminate public housing, to limit the analysis to privately-owned, occupied housing. Exhibit 3-9 summarizes the projections for housing stock and children < 1 year old for the years 1990 through 2050. Also shown there is the probability of a new child being born into a home in each year, which is simply the number of children < 1 year old divided by the number of total occupied homes for that year.

In addition to the overall change in the size of the housing stock, the model incorporated assumptions regarding the distribution of homes between those with and without lead paint. As noted in Section 3.1.1, it was assumed that all homes built between 1980 and 1994 are free of lead paint and have lead soil and dust characteristics like those in the pre-1980 housing stock without lead paint. Similarly, it was assumed that all new housing added to the stock for the remaining 49 years of the model time frame would be added proportionately to the groups of homes without lead paint

It was also assumed that existing homes disappear from the housing stock at a rate of 0.5% per year, based on data derived from the *Annual Housing Survey Components of Inventory Change: 1973 to 1983* (Bureau of Census, 1991). While this factor is assumed to be the same for all types of homes regardless of its age or the presence/absence of lead paint, the effect in this model is to reduce the proportion of lead paint homes relative to the total number of homes over the modeling period. In 1994, it is estimated from the HUD data that approximately 51 million of the 96 million privately-owned occupied homes have either interior or exterior lead paint, comprising 53% of the total.

Exhibit 3-9. Estimated Size of US Privately-Owned Housing Stock and Children < 1 Year Old for 1990 - 2050

Year	Total Occupied Homes	Occupied Privately-Owned Homes	Children < 1 Year Old	Probability of a Child < 1 Year Old
1990	93,345	91,877	4,008	0.0429
1991	94,495	92,991	3,984	0.0422
1992	95,645	94,105	3,960	0.0414
1993	96,795	95,219	3,936	0.0407
1994	97,945	96,333	3,912	0.0399
1995	99,095	97,448	3,889	0.0392
1996	100,245	98,562	3,865	0.0386
1997	101,395	99,676	3,841	0.0379
1998	102,545	100,790	3,817	0.0372
1999	103,695	101,904	3,793	0.0366
2000	104,845	103,018	3,769	0.0359
2001	105,840	103,980	3,796	0.0359
2002	106,835	104,943	3,823	0.0358
2003	107,830	105,905	3,850	0.0357
2004	108,826	106,868	3,877	0.0356
2005	109,821	107,830	3,904	0.0355
2006	110,816	108,793	3,930	0.0355
2007	111,811	109,755	3,957	0.0354
2008	112,806	110,717	3,984	0.0353
2009	113,801	111,680	4,011	0.0352
2010	114,797	112,642	4,038	0.0352
2011	115,926	113,739	4,066	0.0351
2012	117,055	114,835	4,093	0.0350
2013	118,184	115,931	4,121	0.0349
2014	119,313	117,027	4,149	0.0348
2015	120,442	118,124	4,177	0.0347
2016	121,571	119,220	4,204	0.0346
2017	122,700	120,316	4,232	0.0345
2018	123,829	121,413	4,260	0.0344
2019	124,958	122,509	4,287	0.0343
2020	126,087	123,605	4,315	0.0342
2021	126,999	124,484	4,327	0.0341
2022	127,911	125,364	4,338	0.0339
2023	128,823	126,243	4,350	0.0338
2024	129,735	127,122	4,361	0.0336
2025	130,647	128,001	4,373	0.0335
2026	131,559	128,881	4,385	0.0333
2027	132,470	129,760	4,396	0.0332
2028	133,382	130,639	4,408	0.0330
2029	134,294	131,518	4,419	0.0329
2030	135,206	132,397	4,431	0.0328
2031	136,031	133,190	4,458	0.0328
2032	136,856	133,982	4,485	0.0328
2033	137,682	134,774	4,513	0.0328
2034	138,507	135,567	4,540	0.0328
2035	139,332	136,359	4,567	0.0328
2036	140,157	137,152	4,594	0.0328
2037	140,982	137,944	4,621	0.0328
2038	141,807	138,736	4,649	0.0328
2039	142,632	139,529	4,676	0.0328
2040	143,457	140,321	4,703	0.0328
2041	144,178	141,009	4,726	0.0328
2042	144,899	141,697	4,748	0.0328
2043	145,620	142,385	4,771	0.0328
2044	146,341	143,073	4,793	0.0328
2045	147,061	143,761	4,816	0.0327
2046	147,782	144,450	4,838	0.0327
2047	148,503	145,138	4,861	0.0327
2048	149,224	145,826	4,883	0.0327
2049	149,945	146,514	4,906	0.0327
2050	150,666	147,202	4,928	0.0327

Over the 50 year period, with an annual loss rate of 0.5%, these 51 million homes would decrease to about 39.7 million ($51 * 0.995^{50}$). At the same time, the total occupied privately-owned housing stock in 2043 is estimated to be 142.4 million. Therefore, in 2043, the final year of the modeling time frame, houses with either interior or exterior lead paint are estimated to comprise only 28% of the total.

The modeling of these temporal changes in the size of the housing stock, proportion of lead paint housing, and birth rates could be done by "brute force," iterating through each of the 50 years of the model time frame to calculate the incidence separately in each year, and then sum across all years to arrive at the total. A computational shortcut was used, however, taking advantage of the fact that children born into any one of the 1,271 housing categories will have the same predicted blood lead distribution regardless of the year in which those children are born. The number of children to whom that distribution applies will vary from year to year reflecting changes in the size of the housing stock and the birth rate. However, the blood lead distribution for children in that category of homes will remain the same.

The computed incidence of adverse health effects is a function of blood lead distributions and the number of children in the population characterized by those distributions. Since the predicted blood lead distributions are constant in each category of homes over time, the total incidence of adverse effects to all children born into a particular category of homes over time is related to that total number of children. Therefore, the ratio of total children expected to be born into those homes over the full modeling time frame to the number of children born in the first year can be used as a multiplier to apply to the incidence of adverse effects calculated for the children born in the first year to obtain the incidence of adverse effects for children born over the entire modeling time frame.

Sections 3.1.4.1 and 3.1.4.2 discuss the derivation of these multipliers for homes with lead paint and homes without lead paint, respectively. There are different multipliers for these two types of homes because of the difference in housing dynamics for each (i.e., the number of lead paint homes is decreasing over time while the number of non-lead paint homes is increasing). Note, however, that among all HUD-based categories of homes with lead paint, the multiplier is the same. Similarly, there is just one multiplier for all of the HUD-based categories of homes without lead paint.

The notation used for the variables in these derivations tends to be intricate, and so a summary of the key variables with various notations is provided in Exhibit 3-10.

Exhibit 3-10

Summary of Key Variables Used in Derivation of Model Multipliers

B_i	Probability of having a child born into a home in Model Year *i*..
$C_{\Sigma 50}^{T\|LP}$	Total number of children born into lead paint homes over the full modeling time frame.
$C_1^{FB\|LP}$	First born children in lead paint homes in Model Year 1.
$C_i^{FB\|LP}$	First born children in lead paint homes in Model Year *i*.
$C_{\Sigma 50}^{FB\|LP}$	Total first born children in lead paint homes over the full modeling time frame.
$C_i^{T\|LP}$	Total number of children born into lead paint homes over the full modeling time frame in which the first child is born in Model Year *i*..
H_i^{*LP}	Number of lead paint homes in Model Year *i* that have not yet had a child born into them. For $i=1$ this is the number of lead paint homes in 1994 (= 49,130 million).
$C_{\Sigma 50}^{T\|NLP}$	Total number of children born into non-lead paint homes over the full modeling time frame.
$C_{\Sigma 50}^{FB\|NLP(j)}$	Number of first born children in non-lead paint homes added to the housing stock in Model Year *j* .
$H_i^{*NLP(j)}$	Number of non-lead paint homes added to the housing stock in Model Year *j* that have not yet had a first child born into them in Model Year *i* . For $i=1, j=1$ this is the number of non-lead paint homes in the housing stock in 1994 (= 47,203 million).

Each multiplier involves two components. The first component is to account for the total number of "first born" children in homes over the full modeling time frame. That is, for 1994 (the first model year) we estimate the number of children born based on the number of homes present and the per-home probability of a child being born. In the second year, another portion of homes will have a first born child based on the number of homes in the second year that haven't yet had a child and the per-home birth probability for the second year. Similarly, over each of the remaining 50 years, there will be a particular number of "first born" children. The first multiplier component addresses the total of these first born children during the 50 year period of 1994 to 2043.

The second component of the multiplier accounts for the expected number of additional children born subsequently into those homes that have already had a first child born into them. For this second component, we have estimated the expected number of additional children that would be born during additional 50 year time period beyond the birth of the first child. That is, for homes having a first child born in the first model year of 1994, the second part of the multiplier reflects an estimate for additional children born in these homes through 2043. For homes not having a first child born until the last model year of 2044, the multiplier reflects the expected number of additional children born in those homes through 2093.

Multiplier for homes with lead paint

The overall multiplier for homes with lead paint can be expressed as:

$$M^{LP} = \frac{C_{\Sigma 50}^{T|LP}}{C_1^{FB|LP}} \qquad \text{Equation 3-11}$$

where: $C_{\Sigma 50}^{T|LP}$ is the total number of children born into homes with lead paint, and
$C_1^{FB|LP}$ is the number of children born into homes with lead paint in Model Year 1 (1994).

As noted above, the first component of the multiplier addresses the total number of first born children over the 50 year modeling time frame. The number of first births in lead paint homes in each model year can be computed as:

$$C_i^{FB|LP} = (H_i^{*LP})(B_i) \qquad \text{Equation 3-12}$$

where: $C_i^{FB|LP}$ is the number of first births in lead paint homes in year i;
H_i^{*LP} is the number of lead paint homes in that category in Year *i* that have not yet had a child born into them; and
B_i is the per home probability of a birth for year *i*.

The total number of first births in lead paint homes is, then, the sum of the numbers for each individual year:

$$C_{\Sigma 50}^{FB/LP} = \sum_{i=1}^{50} (H_i^{*LP})(B_i) \qquad \text{Equation 3.13}$$

From the data presented in Exhibit 3-9, we know the value for each B_i (where $i = 1$ for 1994). We also know from the HUD data the value for H_1^{*LP}, which is simply the total number of lead paint homes in 1994, estimated to be 49 million. (Note: This number is higher than the 38.7 million shown in Exhibit 3-1 as having interior XRF values greater than 0, since the definition of lead paint homes used here includes both those with interior and exterior lead paint.

We do not know, directly, the values for H_i^{*LP} for Model Years 2 through 50; however, these values can be derived as follows. For Model Year 2, the number of lead paint homes that have not yet had a child born into them is:

$$H_2^{*LP} = (H_1^{*LP} - (H_1^{*LP} \bullet B_1)) \bullet 0.995 \qquad \text{Equation 3.14}$$

That is, the number of homes at the start of Model Year 2 not yet having a first birth is equal to the number at the start of in Model Year 1 not having a first birth, less the number that do have a child born in Model Year 1, reduced by 0.5% to account for loss in the housing stock that year.

Similarly, the number for Model Year 3 can be expressed as:

$$H_3^{*LP} = (H_2^{*LP} - (H_2^{*LP} \bullet B_2)) \bullet 0.995 \qquad \text{Equation 3.15}$$

Note that the values for Model Year 3 are expressed in terms of Model Year 2 values, which in turn are expressed in terms of Model Year 1 values. Therefore, the expression for Model Year 3 can be written in terms of Model Year 1 values as:

$$\begin{aligned} H_3^{*LP} &= (H_2^{*LP} - (H_2^{*LP} \bullet B_2)) \bullet 0.995 \\ &= (H_2^{*LP}) \bullet (1 - B_2) \bullet 0.995 \\ &= (H_1^{*LP}) \bullet (1 - B_1) \bullet 0.995 \bullet (1 - B_2) \bullet 0.995 \end{aligned} \qquad \text{Equation 3.16}$$

Similarly, the value for each subsequent year can also be expressed in terms of the birth rates for each year and the (constant) value H_1^{*LP}.

This can be generalized as:

$$H_i^{*LP} = H_1^{*LP} \bullet \left(\prod_1^i (1 - B_i)\right) \bullet 0.995^{i-1} \qquad \text{Equation 3.17}$$

Substituting this for H_i^{*LP} into Equation 3-13 gives:

$$\begin{aligned} C_{\Sigma 50}^{FB|LP} &= \sum_{i=1}^{50} H_1^{*LP} \bullet \left(\prod_1^i (1 - B_i)\right) \bullet 0.995^{i-1} \bullet (B_i) \\ &= H_1^{*LP} \bullet \sum_{i=1}^{50} \left(\prod_1^i (1 - B_i)\right) \bullet 0.995^{i-1} \bullet (B_i) \end{aligned} \qquad \text{Equation 3.18}$$

We can now compute the number of first born children in the lead paint homes from the birth rate information in Exhibit 3-9, and the number of lead paint homes. We can also express an interim multiplier as the ratio of all first born children in lead paint homes over the 50 year time frame to the first born children in lead paint homes in Model Year 1 as:

$$M^{FB|LP} = \frac{C^{FB|LP}_{\Sigma 50}}{C^{FB|LP}_1} = \frac{H^{*LP}_1 \bullet \sum_{i=1}^{50}\left(\prod_1^i (1-B_i)\right) \bullet (B_i) \bullet 0.995^{i-1}}{H^{*LP}_1 \bullet B_1} = \frac{\sum_{i=1}^{50}\left(\prod_1^i (1-B_i)\right) \bullet (B_i) \bullet 0.995^{i-1}}{B_1} \qquad \text{Equation 3.19}$$

It is useful to note that for this multiplier, the value for H^{*LP}_1 drops out. Therefore, the first birth component of the multiplier for lead paint homes is a function only of the birth rates over the 50 year period and the assumed loss rate of 0.5% per year. From the data in Exhibit 3-11, it can be shown that the value for $M^{FB|LP}$ is:

$$\frac{0.7623}{0.03994} = 19.08 \qquad \text{Equation 3.20}$$

The summation values for each model year that result in 0.7623 for the numerator are shown in Exhibit 3-11. The denominator value of 0.03994 is the per home birth probability for 1994.

As noted above, this interim multiplier addresses only the number of total first births in lead paint homes. That is, the total number of first births in lead paint homes from 1994 to 2043 is 19.08 times the number of first births in 1994.

To obtain the second component of the multiplier that accounts for additional children expected to be born into the homes subsequent to the first child, we begin with the 1994 birth rate multiplied by 50 to obtain the expected number of children over an ensuing 50 year period. This value is:

$$(0.03994)\ (50) = 1.998 \qquad \text{Equation 3.21}$$

However, since these homes are being lost from the stock at a rate of 0.5% per year, it is necessary to adjust this number downward to account for homes that will be lost before this additional 50 years is complete. The probability that a home survives through 50 years with an annual loss rate of 0.5% is given by:

$$(1 - 0.005)^{50} = (0.995)^{50} = 0.778 \qquad \text{Equation 3.22}$$

Exhibit 3-11. Elements of Summation Component for Numerator in Equation 3.19

i	B_i	$(1-B_i)$	$\prod_1^i (1-B_{i-1})$	$(0.995)^{i-1}$	i th Year Quantity of Summation
0	0	1.0000	--	--	--
1	0.0399	0.9601	1.0000	1.0000	0.0399
2	0.0392	0.9608	0.9601	0.9950	0.0375
3	0.0386	0.9614	0.9224	0.9900	0.0352
4	0.0379	0.9621	0.8868	0.9851	0.0331
5	0.0372	0.9628	0.8532	0.9801	0.0311
6	0.0366	0.9634	0.8215	0.9752	0.0293
7	0.0359	0.9641	0.7914	0.9704	0.0276
8	0.0359	0.9641	0.7630	0.9655	0.0264
9	0.0358	0.9642	0.7356	0.9607	0.0253
10	0.0357	0.9643	0.7093	0.9559	0.0242
11	0.0356	0.9644	0.6840	0.9511	0.0232
12	0.0355	0.9645	0.6596	0.9464	0.0222
13	0.0355	0.9645	0.6362	0.9416	0.0212
14	0.0354	0.9646	0.6136	0.9369	0.0203
15	0.0353	0.9647	0.5919	0.9322	0.0195
16	0.0352	0.9648	0.5710	0.9276	0.0187
17	0.0352	0.9648	0.5508	0.9229	0.0179
18	0.0351	0.9649	0.5315	0.9183	0.0171
19	0.0350	0.9650	0.5128	0.9137	0.0164
20	0.0349	0.9651	0.4949	0.9092	0.0157
21	0.0348	0.9652	0.4776	0.9046	0.0150
22	0.0347	0.9653	0.4610	0.9001	0.0144
23	0.0346	0.9654	0.4450	0.8956	0.0138
24	0.0345	0.9655	0.4297	0.8911	0.0132
25	0.0344	0.9656	0.4148	0.8867	0.0127
26	0.0343	0.9657	0.4006	0.8822	0.0121
27	0.0342	0.9658	0.3868	0.8778	0.0116
28	0.0341	0.9659	0.3736	0.8734	0.0111
29	0.0339	0.9661	0.3609	0.8691	0.0106
30	0.0338	0.9662	0.3486	0.8647	0.0102
31	0.0336	0.9664	0.3368	0.8604	0.0097
32	0.0335	0.9665	0.3255	0.8561	0.0093
33	0.0333	0.9667	0.3146	0.8518	0.0089
34	0.0332	0.9668	0.3041	0.8475	0.0086
35	0.0330	0.9670	0.2940	0.8433	0.0082
36	0.0329	0.9671	0.2843	0.8391	0.0079
37	0.0328	0.9672	0.2750	0.8349	0.0075
38	0.0328	0.9672	0.2660	0.8307	0.0072
39	0.0328	0.9672	0.2572	0.8266	0.0070
40	0.0328	0.9672	0.2488	0.8224	0.0067
41	0.0328	0.9672	0.2407	0.8183	0.0065
42	0.0328	0.9672	0.2328	0.8142	0.0062
43	0.0328	0.9672	0.2251	0.8102	0.0060
44	0.0328	0.9672	0.2178	0.8061	0.0058
45	0.0328	0.9672	0.2106	0.8021	0.0055
46	0.0328	0.9672	0.2037	0.7981	0.0053
47	0.0328	0.9672	0.1970	0.7941	0.0051
48	0.0328	0.9672	0.1906	0.7901	0.0049
49	0.0328	0.9672	0.1843	0.7862	0.0047
50	0.0328	0.9672	0.1783	0.7822	0.0046
			$\sum_{i=1}^{50} \left(\prod_1^i (1-B_i)\right) \bullet (B_i) \bullet 0.995^{i-1}$		0.7623

Combining these, the expected number of children born into homes having had a first child is:

$$(1.998)\ (0.778) = 1.55 \qquad \text{Equation 3.23}$$

Therefore, for each first born child in a home in each year, there is an expected number of 1.55 additional children over the ensuing 50 years.

The total number of children over the full modeling time frame expressed in terms of the number of first born children each year is:

$$C_i^{T|LP} = C_i^{FB|LP} + 1.55C_i^{FB|LP} = 2.55C_i^{FB|LP} \qquad \text{Equation 3.24}$$

Thus the total number of children expected to be born into lead paint home is given by:

$$C_{\Sigma 50}^{T|LP} = \sum_{i=1}^{50} C_i^{T|LP} = \sum_{i=1}^{50}\left(2.55C_i^{FB|LP}\right) = 2.55\sum_{i=1}^{50} C_i^{FB|LP} \qquad \text{Equation 3.25}$$

Since:

$$C_{\Sigma 50}^{FB|LP} = \sum_{i=1}^{50} C_i^{FB|LP} \qquad \text{Equation 3.26}$$

and, as can be seen from the numerators in Equations 3-19 and 3-20,

$$C_{\Sigma 50}^{FB|LP} = H_1^{*LP} \bullet 0.7623 \qquad \text{Equation 3.27}$$

the overall multiplier for lead paint homes can be expressed as:

$$M^{LP} = \frac{C_{\Sigma 50}^{T|LP}}{C_1^{FB|LP}} = \frac{2.55 \bullet H_1^{*LP} \bullet 0.7623}{H_1^{*LP} \bullet B_1}$$

$$= \frac{2.55 \bullet 0.7623}{0.03994} \qquad \text{Equation 3.28}$$

$$= 48.65$$

Therefore, to estimate the total incidence of adverse effects for children born in lead paint homes, the incidence of adverse effects obtained for the first year cohort is multiplied by 48.65.

Multiplier for homes with no lead paint

Obtaining the multiplier for the homes without lead paint is conceptually similar to the derivation for homes with lead paint, but the computation is complicated by the nature of the change in the size of the stock of these homes over the 50 year modeling period. For lead paint homes, the stock was assumed to change with a constant loss rate over the 50 year period of 0.5% per year. As a result, a constant term could be used in the Equations (see, for example ???) to reflect this rate. In the case of homes without lead paint, however, the annual rate of change is not constant. As shown in Exhibit 3-9, the total number of privately-owned homes increases each year from 1994 through 2043. It is assumed that the new homes added each year are free of lead paint.

It is important to note that the number new homes added to the housing stock in a given year is not just the difference between the total for that year and the total for the previous year. Since older homes (both with and without lead paint) are disappearing at a rate of 0.5% per year, the number of new, no lead paint homes each year is the sum of the difference between the totals for those years, plus 0.5% of the preceding year's total stock.

To derive the multiplier for homes without lead paint, it is useful to consider these homes in terms of 50 separate groups. The first group is the non-lead paint homes that are present in Model Year 1. The remaining 49 groups are the new, non-lead paint homes added to the stock each remaining year. It is assumed that each of these 50 groups has the same loss rate characteristic as noted in the preceding section for homes with lead paint. That is, it is assumed that they disappear from the stock with the same annual loss rate of 0.5%. By using this approach, we can develop equations similar to those for homes with lead paint (i.e., having the constant loss rate of 0.5% per year) to determine the total number of first births in these homes from the year they are added to the stock through the end of Model Year 50. The first birth obtained for each of these 50 groups can then be summed, and a multiplier obtained expressed as the ratio of this sum to the number of first birth children in non-lead paint homes in Model Year 1.

The number of first births over the full 50 years just in the non-lead paint homes that are present in Model Year 1 is expressed as:

$$
\begin{aligned}
C_{\Sigma 50}^{FB/NLP(1)} &= \sum_{i=1}^{50} (H_1^{*NLP(1)})(B_i) \\
&= H_1^{*NLP(1)} \bullet \sum_{i=1}^{50} \left(\prod_1^i (1 - B_i) \right) \bullet (B_i) \bullet 0.995^{i-1}
\end{aligned}
\qquad \text{Equation 3.29}
$$

which is similar in form to Equation 3-18.

For the new lead paint homes added in Model Year 2, the number of first births through Model Year 50 is given by:

$$C_{\Sigma 50}^{FB/NLP(2)} = \sum_{i=2}^{50}(H_i^{*NLP(2)})(B_i)$$
$$= H_2^{*NLP(2)} \bullet \sum_{i=2}^{50}\left(\prod_2^i (1-B_i)\right) \bullet (B_i) \bullet 0.995^{i-2} \qquad \text{Equation 3.30}$$

Note that here the summation begins with Model Year 2.

Similarly, for homes that enter the stock in model year 3, the number of first births over the duration of model year 3 to model year 50 is:

$$C_{\Sigma 50}^{FB/NLP(3)} = \sum_{i=3}^{50}(H_i^{*NLP(3)})(B_i)$$
$$= H_3^{*NLP(3)} \bullet \sum_{i=3}^{50}\left(\prod_3^i (1-B_i)\right) \bullet (B_i) \bullet 0.995^{i-3} \qquad \text{Equation 3.31}$$

Again, the summation in this case begins with Model Year 3.

The total number of first births in homes without lead paint is, then, the sum of these first birth calculations for each of the 50 groups of homes:

$$C_{\Sigma 50}^{FB/NLP} = \sum_{j=1}^{50} C_{\Sigma 50}^{FB/NLP(j)} \qquad \text{Equation 3.32}$$

Exhibit 3-12 shows the first birth values calculated for each of 50 groups of non-lead paint homes over the 50 year time frame, as well as the sum of these, shown there to be 73,648 M children. To convert this to an interim multiplier addressing only first births, both sides of Equation 3.32 are divided by the number of first births in non-lead paint homes in Model Year 1:

$$M^{FB/NLP} = \frac{C_{\Sigma 50}^{FB/NLP}}{C_1^{FB/NLP(1)}} = \frac{\sum_{j=1}^{50} C_{\Sigma 50}^{FB/NLP(j)}}{C_1^{FB/NLP(1)}} = \frac{\sum_{j=1}^{50} C_{\Sigma 50}^{FB/NLP(j)}}{H_1^{*NLP(1)} \bullet B_1} \qquad \text{Equation 3.33}$$

Using the values shown in Exhibit 3-12 of 73,648 for the numerator and 47,203 for the number of non-lead paint homes in Model Year 1 in the denominator, as well as the value of 0.03994 in the denominator for the per home probability of birth described previously, an interim "first birth" multiplier is obtained as:

$$M^{FB/NLP} = \frac{73{,}648}{(47{,}203)(0.03994)} = 39.06 \qquad \text{Equation 3.34}$$

Exhibit 3-12

Summary of New Non-Lead-Paint Homes and First Births in These Homes over the 50 Year Model Period

Model Year (i)	New, No-Lead-Paint Homes in this Model Year	Total "First Births" in This Year's New Homes Through 2043
1	47,203	35,982
2	1,596	1,207
3	1,601	1,201
4	1,607	1,195
5	1,612	1,189
6	1,618	1,182
7	1,624	1,176
8	1,478	1,060
9	1,482	1,053
10	1,487	1,046
11	1,492	1,038
12	1,497	1,030
13	1,502	1,021
14	1,506	1,011
15	1,511	1,001
16	1,516	991
17	1,521	980
18	1,660	1,053
19	1,665	1,039
20	1,670	1,025
21	1,676	1,010
22	1,681	994
23	1,687	978
24	1,692	960
25	1,698	942
26	1,703	922
27	1,709	902
28	1,497	769
29	1,502	749
30	1,506	729
31	1,510	707
32	1,515	685
33	1,519	661
34	1,524	637
35	1,528	611
36	1,532	584
37	1,537	556
38	1,454	497
39	1,458	469
40	1,462	438
41	1,466	407
42	1,470	374
43	1,474	339
44	1,478	303
45	1,482	265
46	1,486	226
47	1,490	185
48	1,390	132
49	1,393	90
50	1,397	46
Total No-Lead-Paint Homes with "First Births" Through 2043		73,648

Therefore, the total number of first births in homes with no lead paint over the 50 year model period is computed as 39.06 times the number of first births in non-lead paint homes in model year 1. To obtain the overall multiplier to account for both first birth and subsequent births in these homes, the additional factor of 2.55 is applied, as described previously for homes with lead paint. Thus, the overall multiplier is:

$$M^{TINLP} = (39.06)(2.55) = 89.60 \qquad \text{Equation 3.35}$$

Therefore, to obtain the total incidence of adverse effects for children born into homes without lead paint, the incidence computed for children born into those homes in the first model year is multiplied by 89.60.

3.1.5 Discussion of Results for Baseline Risk Assessment

The discussion of the results of the baseline risk assessment focuses on the blood lead distribution obtained for the first year of the model period. Because most of the other measures of adverse health effects (e.g., incidence of IQ point losses) are difficult to interpret until combined with information on the value of those damages and the societal benefits attained by avoided those damages, these latter aspects are addressed in subsequent chapters of this document addressing benefits and benefit-cost comparisons.

As discussed in the preceding sections, the blood lead distribution for the first model year cohort of children is obtained by separately estimating blood lead distribution geometric means for 1,271 groups of children associated with homes that are differentiated by their paint, soil and dust levels (plus paint condition and pica potential). The geometric means are based on the value obtained from the IEUBK for children exposed to those conditions continually from birth through age 7, with the blood lead for age three used as the representative value. Along with these estimated geometric means, the blood lead distributions for these 1,271 groups of children are all assumed to have a geometric standard deviation of 1.6.

Exhibit 3-13 depicts the distribution of geometric means resulting from this modeling process. As shown by this histogram, the distribution of the GMs is right skewed, with most children expected to be in homes where GMs are expected to be in the range of 1 to 6 ug/dl, with generally decreasing frequencies of GMs at higher values. The maximum GM predicted for any housing category was 30.1 ug/dl.

Again, these values are the predicted geometric means for 1,271 groups of children. The overall population distribution of blood lead levels was obtained by first estimating the number of children in each 1 ug/dl range from 1 to 50 ug/dl (plus a total for those exceeding 50 ug/dl) for each of these 1,271 distributions using the standard normal distribution function. The geometric standard deviation used in all of these computations was assumed to be a constant 1.6 for all group, as discussed before.

Exhibit 3-13
Distribution of Predicted Baseline Geometric Means for First Year Cohort

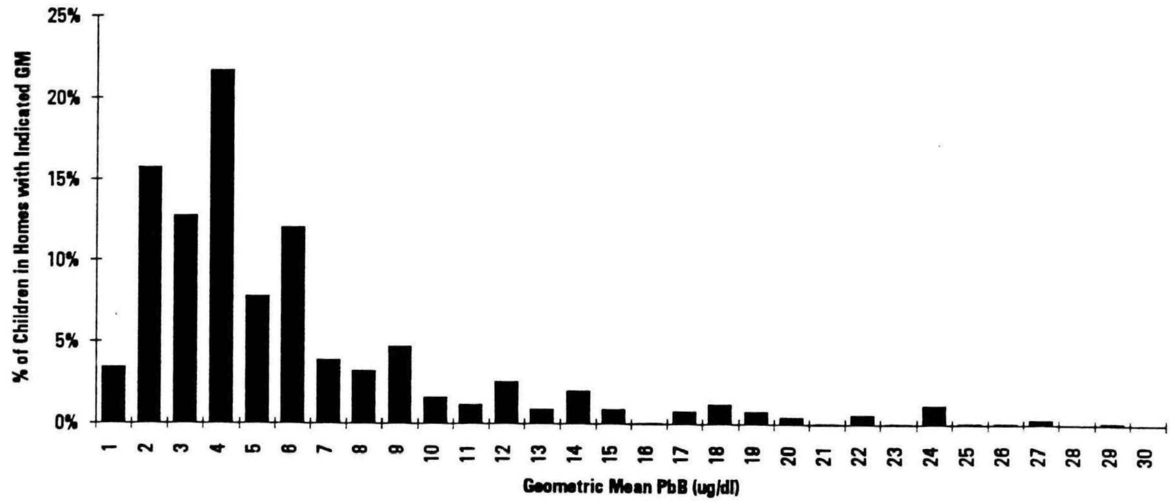


Exhibit 3-14
Distribution of Predicted Baseline Population Blood Lead Levels for First Model Year Cohort
(1994)

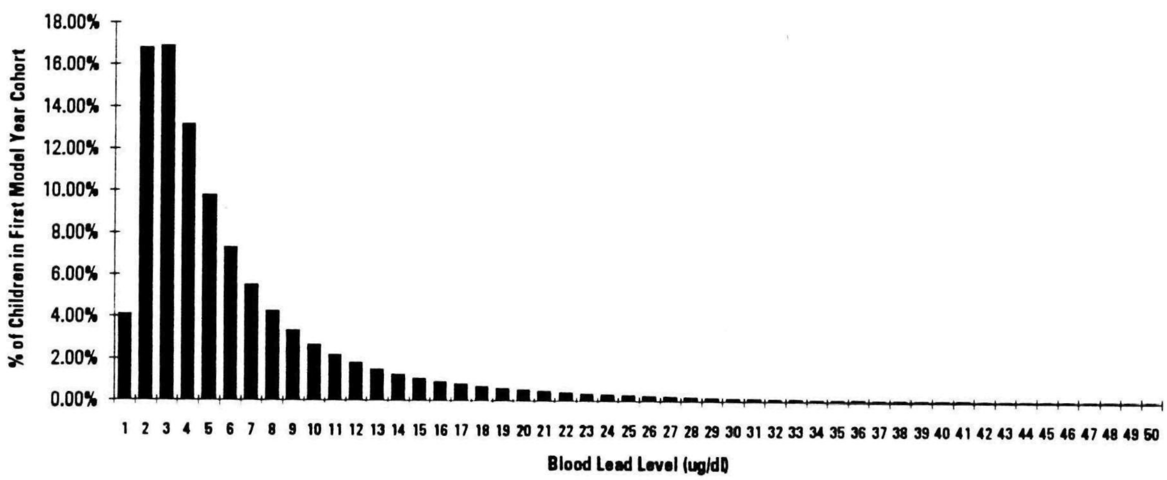


Exhibit 3-15

Characteristics of Baseline Population Blood Lead Distribution and a Distribution with GM = 5, GSD = 1.6

	From Modeled Baseline Distribution	From a Distribution with GM = 5.0 and GSD = 1.6
Mean	6.09 ug/dl	5.58 ug/dl
Geometric Mean	4.06 ug/dl	5.00 ug/dl
Geometric Standard Dev.	2.45 ug/dl	1.60 ug/dl
Median	3.91 ug/dl	5.00 ug/dl
90th Percentile	13.32 ug/dl	9.13 ug/dl
95th Percentile	18.85 ug/dl	10.83 ug/dl
% > 10 ug/dl	15.99%	7.01%
% > 15 ug/dl	8.03%	0.97%
% > 20 ug/dl	4.37%	0.16%
% > 25 ug/dl	2.47%	0.03%

To arrive at the overall population blood lead distribution for the first year cohort, the predicted number of children in each 1 ug/dl range for all 1,271 groups were added together. Exhibit 3-14 provides a histogram of the overall distribution arrived at by this process. Exhibit 3-15 summarizes the characteristics of this distribution.

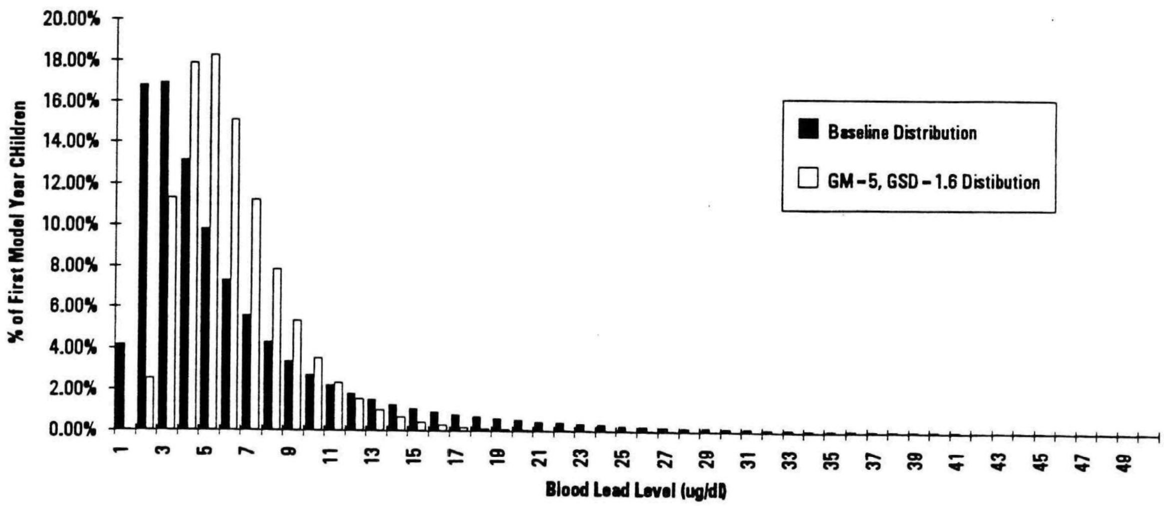
The mean shown in Exhibit 3-15 was obtained by assuming a mid-point value in each of the 50 concentrations ranges (e.g., a value of 5.5 ug/dl was used for the children predicted to fall between 5 and 6 ug/dl). The geometric mean was obtained in a similar manner by taking the natural logs of these values, computing the mean of the log values and exponentiating. The geometric standard deviation was obtained from the normal formula for a sample standard deviation, using the log transformed values and weighting the differences between the mean of the logs and the log of the mid-points of each range by the number of children in that range.

For comparison, values are also included in Exhibit 3-15 for a lognormal distribution having the parameters of GM=5 and GSD=1.6, which has been suggested by Schwartz (1993a) as the current population blood lead distribution parameters for children under 7. Exhibit 3-16 superimposes a histogram based on the GM=5, GSD=1.6 parameters onto the baseline population blood lead distribution histogram shown previously in Exhibit 3-10.

The central tendency values for the modeled baseline distribution and the GM=5, GSD=1.6 distribution are slightly lower than those for the GM=5, GSD=1.6 distribution, reflected by the lower values for the geometric mean and median. The GM=5, GSD=1.6 distribution indicates higher values than the model in the range of abut 5 to 11 ug/dl, after which point the model values exceed the GM=5, GSD=1.6 distribution values.

Cumulatively, the modeled distribution is far more right skewed than the GM=5, GSD=1.6 distribution, however. For example, only 7% of the population would be expected to exceed 10 ug/dl from the GM=5, GSD=1.6 distribution, whereas the model predicts over twice that frequency (16%).

Exhibit 3-16
Comparison of Baseline Blood Lead Distribution with GM=5, GSD=1.6 Distribution



The GM=5, GSD=1.6 distribution also predicts only about 0.03% of the population exceeding 25 ug/dl, whereas as the model predicts almost 2.5%. Schwartz (1993a) has suggested that this value is currently about 0.5% to 1% based on a preliminary assessment of the NHANES III data.

It is useful to examine the source of the population above 25 ug/dl predicted by the model. Exhibit 3-17 provides a summary of the distribution of the blood lead levels above 25 ug/dl predicted by the model among different exposure conditions. As shown there, children with pica in homes having lead paint in bad condition have the highest individual risk of blood leads exceeding 25 ug/dl, at 9.2%. By comparison, children in homes with either interior of exterior lead paint, but without ingesting paint chips have a predicted incidence of blood lead above 25 ug/dl of about 3%. Children in homes without lead paint are predicted to have blood leads above 25 ug/dl only 1.6% of the time.

Notwithstanding the higher predicted rate of high blood leads for children ingesting lead paint chips, the overall number of such children predicted is only about 9% of the total having these high blood leads. Other sources have suggested that paint chip ingestion is a much larger contributor to these high blood leads than these results show. For example, Shannon and Graef (1992) found that paint chip ingestion was the origin of elevated blood leads for 80-90% of toddlers with elevated blood leads entering the Lead/Toxicology Program at Boston's Children Hospital. For infants, by contrast, paint chip ingestion appeared to account for only about 20% of the cases.

Exhibit 3-17

Blood Leads > 25 Related to Exposure Conditions

Exposure Conditions	Total Children in First Year	# > 25	% > 25
Interior lead paint in bad condition, paint chip ingestion	94,271	8,688	9.22%
Interior lead paint (may also have exterior lead paint), any condition, no paint chip ingestion	1,476,903	43,971	2.98%
Exterior lead paint, no interior lead paint, no paint chip ingestion	406,957	12,416	3.05%
No interior or exterior lead paint, no paint chip ingestion	1,937,141	31,548	1.63%
Totals:	3,915,272	96,623	2.47%
Percent of PbB >25 related to paint chip ingestion			8.99%
Odds ratio of PbB > 25 for Lead paint present : No lead paint present			2.02

Also, Schwartz and Levin (1991) found that the odds ratio of having blood leads exceeding 30 ug/dl ranged from 5.70 to 12.81 given paint lead exposure. The population studied was children i n Chicago for 1976 through 1980, when leaded gasoline was still a major contributor of elevated blood leads. One would expect, therefore, a higher odds ratio currently than observed in those data. However, the model results indicate an odds ratio of only about 2.

Except for 8,688 children predicted to have blood leads above 25 ug/dl due to paint chip ingestion, all other cases of high blood leads in the model are occurring from ingestion of soil and/or dust having somewhat elevated lead levels. The lead levels in these soils and dusts for most of the approximately 88,000 non-pica children with high blood leads tend to be above 1,000 ppm. Approximately 76,000 of these cases (86%) occur in cases when dust levels exceed 1,000 ppm, and 32,500 (37%) occur when soil levels exceed 1,000 ppm.

Since there is some overlap between these, a weighted average of the soil and dust lead levels was computed, using 55% dust and 45% soil (the assumption made for ingestion in the IEUBK model). Over 81,000 children with blood leads above 25 ug/dl (92% of the non-pica group) are exposed to weighted average soil/dust concentrations of 1,000 ppm or more, and about 54,000 (61%) are at or above weighted average soil/dust concentrations of 2,000 ppm.

3.2 MARKET FAILURE

From an economic perspective, one necessary condition for regulatory intervention is the existence of an inefficiency in the allocation of resources. This inefficiency is commonly labeled a market failure since the market is the mechanism assumed to make efficient resource allocations possible. The cause of a market failure can come from one or more of several sources. These include poorly defined property rights (such as negative externalities, common property resources, and public goods); imperfect markets for trading property rights (because of a lack of perfect information or of contingent markets; monopoly power; distortionary taxes and subsidies and other inappropriate government interventions); and the divergence of private and social discount rates.[2]

The occurrence of any of these conditions justifies further inquiry into the need for government intervention to reduce inefficiencies in the allocation of society's resources. This section considers whether any of these conditions are linked to excess exposures from lead contamination in residential soil, dust, and paint. If so, a better understanding of the nature of the inefficiencies involved may facilitate the design of effective interventions. The specific intervention considered here is the promulgation of hazard levels as mandated by Section 403.

The strongest case for the existence of a market failure can be built on the apparent lack of perfect information. The right information is an important prerequisite to the demand for abatement. The homeowner making the abatement decision has to know the levels of lead in soil, dust, or paint; know what risks are implied by these levels; know the significances of these risks; and know what can be accomplished through various forms of abatement. Clearly, without knowing there is a lead problem, the homeowner will have too low a demand for abatement. Misinformation on the other attributes of the abatement decision can also distort the demand for abatement. Research into public views of risk indicate how common misperceptions are in the assessment of latent risks like those associated with lead contamination. These misperceptions can be biased upward or downward, resulting respectively in excess and insufficient demand for abatement. Finally, reliable information on the relative and absolute effectiveness of different abatement alternatives could be a significant obstacle.

The market itself has not provided a means for correcting the situation. Although businesses offering testing or abatement services should find it in their vested interest to offer the kinds of information cited above, this possibility has not closed the information gaps for the public. One impediment may be public uncertainty about the reliability of the information that such businesses would provide. Their information may be unreliable because they are not fully competent to assess the lead contamination and what needs to be done, because the businesses are subject to moral hazard (which occurs, for example, when a firm tells a homeowner that there is a lead problem that warrants a certain abatement it can perform when the abatement is not necessary or suitable), or both. Since many homeowners may lack easy access to independent sources of information to motivate their abatement decisions, doing nothing may be the likely response.

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2 This taxonomy was developed from (Axelrad, 1993) and (Boadway, 1979).

While lamentable, this lack of action is understandable given limits on the time and money that a homeowner can actually spend on obtaining information needed for many different decisions. Even though homeowners, as parents, may be deeply concerned about the welfare of their children - a key target of exposure from lead contamination - there are a host of other issues besides lead which affect their children's welfare and for which parents need information to make important decisions. These other information needs compete with the information needs of the lead abatement decision for scarce household resources. Given how little abatement has been initiated by homeowners relative to the prevalence of the problem, the likelihood that there is insufficient demand for abatement and that information gaps contribute to this circumstance appears to be high. In conclusion, it appears that at least one condition associated with market failures holds and, consequently, that inefficiencies may characterize the market for lead testing and abatement.

Before a final determination can be made about the inefficiencies associated with the lack of information, the costs of spanning the information gaps must be considered. One of the more important unknown variables in setting hazard levels under Section 403 is what approaches to making information available will actually get homeowners to test, to consider the abatement alternatives, and to undertake abatement where appropriate. This analysis represents one step in shedding light on approaches that reduce possible inefficiencies.

A central question is whether government intervention can make the right information available to increase the demand for abatement. In attempting to answer this question, it is helpful to consider the public good aspect of promulgating hazard levels. To the extent the public finds them credible and takes steps to measure lead contamination, the hazard levels provide an independent benchmark for action, lessening at least part of the information needed to make an abatement decision. As such, hazard levels can qualify as a public intermediate good since they can be used simultaneously by many households in making their abatement decisions.[3] Whether the hazard levels are a public good or not depends finally on whether the abatements induced by the hazard levels result in benefits exceeding the costs. If so, the hazard levels are a public good. If not, they are a public bad. The analysis in this report addresses this issue directly by attempting to discriminate between the forms and magnitudes of hazard levels that lead to positive net benefits and those that do not.

Other potential causes of market failure may characterize the persistence of lead contamination in residences. By undertaking abatement, the owner of a home creates positive externalities for any occupants outside of his or her immediate family, such as renters, if the owner is a landlord, and subsequent owners who are occupants of the home. If these renters and subsequent owners are fully informed about the implications of lead contamination, the market may adequately compensate the original owner for undertaking lead abatement and no externality impedes the abatement decision. If they are not fully informed, then the original owner will not be sufficiently compensated for services provided to the renters and subsequent owners. Under these circumstances, too few abatements will be undertaken. It is difficult to measure how large this problem is since it requires information on the stock of knowledge about lead problems held by tenants and purchasers today and in the future.

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[3] The term "public intermediate good" and its definition are adapted from Boadway, 1979.

Compounding the problem of undercompensation is a divergence between social and private discount rates, which matters since this analysis anticipates that occupants as much as fifty years in the future can potentially benefit from the abatement of a given house. Even if each renter or subsequent owner is willing to pay the full market value of the externality provided by the original owner's undertaking lead abatement, it is likely that the private estimate of the present value of these future payments to the original owner will be smaller than the present value based on the social rate of discount. Consequently, by relying on private decisions, fewer abatements will be undertaken. The size of this effect could be estimated using the framework applied in this analysis but has not been conducted to date.

This review suggests there is one or more market failures affecting decisions regarding the abatement of residential lead contamination. The lack of perfect information is a primary culprit. However, the evidence is not conclusive. The ultimate determination of a market failure depends on whether gains in efficiency can be accomplished by some form of intervention. An allocation of resources is deemed inefficient if someone can be made better off without making someone else worse off. That is a core question of this analysis. The discussion of risks from lead contamination does indicate a substantial potential for making individuals' better off by reducing residential exposures from soil, dust, and paint. Consequently, one part of the definition of an inefficient allocation has been met. However, to determine whether the other part of the definition can be satisfied depends on the outcome of the benefit-cost analysis itself. If the benefits of reducing lead exposures exceed all costs, it is possible to accomplish this without making others worse off. The costs that have to be considered include the costs of getting the right people to decide to abate, to choose the right abatement, and to perform and maintain the abatement in the expected manner as well as the direct costs of testing and abatement.

3.3 NEED FOR FEDERAL REGULATION

In the Residential Lead-Based Paint Hazard Reduction Act of 1992 ("the Act"), the United States Congress identified the elimination of lead-based paint hazards as a national goal. Congress found that the Federal Government must take a leadership role in building the required infrastructure, including an informed public, State and local delivery systems, certified inspectors, contractors, and laboratories, trained workers (§1002(8)). By identifying what constitutes a lead-based paint hazard (defined as paint, dust or soil conditions that would result in adverse human health effects), Section 403 creates a crucial portion of the integrated federal regulatory approach necessary to adequately inform the public of the dangers of lead-based paint, and to implement other portions of the Act that require mandatory action if a lead-based paint hazard exists.

The proposed federal identification of lead-based paint hazards will provide guidance to states, localities and individuals in protecting citizen's rights. Such guidance will promote partnerships in developing the most cost-effective ways to address lead-based paint hazards. The Act encourages the individual States to adopt the federal §403 regulations, as well as federal regulations from other sections of the Act, to the specific conditions that exist in the States by utilizing existing State and local programs. Further, States have the option of imposing requirements which are more stringent than the federal procedures. Thus the States may respond to regional diversity and local social choice by building upon the §403 identification while guaranteeing the minimum rights of all citizens.

The Act authorizes certain federal expenditures to partially achieve the national goal of eliminating lead-based paint hazards. Authorized federal expenditures include federal grants for evaluating and reducing lead-based paint hazards in non-publicly owned or assisted housing, risk assessments and interim controls in federally assisted housing, and inspections and abatement of lead-based paint hazards in all federally owned housing constructed prior to 1960. The Section 403 identification of lead-based paint hazards is necessary to implement these federal expenditures in a manner that develops the most promising cost effective methods.

3.4 REGULATORY OPTIONS

Four general classes of instruments are options for government intervention. These are (1) information provision and labelling, (2) performance or technical standards, (3) bans or restrictions on use, and (4) economic incentives. The first of these is most closely linked to the primary condition contributing to a market failure, as described in Section 3.2. Consequently, directly addressing the lack of adequate information will be the focus of the discussion in this section, and in the analysis of this report. Examples of how the other three classes of instruments could be applied are presented but only to illustrate their potential. Further analysis will be required to determine how viable they are.

3.4.1 Information Provision

A draft regulator's guide on economic incentives under TSCA identifies three circumstances that are particularly favorable to making the provision of information an appropriate instrument for intervention (Eyraud, 1993). The first circumstance - that there is a significant lack of information generating exposure problems - has already been identified as a strong likelihood. To rectify this circumstance, a corollary condition has to be met. The new information has to be able to induce exposure-reducing behavior. Information programs are appealing as a means of intervention in part because they do not impose direct burdens on the economy. One of the dangers, though, is that the absence of a direct burden will come at the expense of being ineffective. This does not have to be the case. Collectively, environmental and other public health programs have amassed substantial experience in learning about what works and what does not in risk communication. This expertise will have to be tapped to render any information approach effective.

The second circumstance favorable to effective information provision is one where the exposure is not created by an externality beyond the exposed individuals' control. In other words, the affected population has to be able to put the information to good use. While externalities between current abatement and future beneficiaries were identified as a possible cause of market failure, these do not prevent information from being effective. For example, if a house is not abated over the next 30 years, at least the occupants at that future time can decide to undertake abatement if they have the right information to motivate their decision. This circumstance appears to apply to the exposures from lead in residential soil, dust, and paint. There is however at least one major exception. Financial constraints can prevent even the best informed household from taking effective steps to reduce exposure. As homeowners, households may not be able to afford abatement. As renters and buyers, they not be able to afford housing that has been abated. It is important to note, however, that this hindrance is not unique to an information approach. It is likely to affect other interventions to the same or greater degree.

The third circumstance favorable to the use of an information approach is one where other interventions would lead to greater and significant economic impacts. Although its effects are indirect (working through changes in behavior rather than by direct enforcement), an information approach does create economic impacts. Whether these economic impacts are greater or less than those of other interventions is unknown at this time because other interventions have not been studied in as much depth.

Scope of Analysis

This analysis focuses on the influence that a particular type of information - hazard levels - can have on the abatement decisions of homeowners. Promulgating such hazard levels is one means of implementing Section 403 of TSCA, which calls for EPA to identify lead-based paint hazards, lead-contaminated dust, and lead-contaminated soil. One objective in promulgating such hazard levels is to fill part of the information gap that has been linked to sluggish rates of abatement of lead-contaminated homes. Specifically, these hazard levels are intended to indicate thresholds at which EPA recommends that certain forms of abatement take place. As such, they can lower the information costs for homeowners' making a decision about whether to abate and as a result increase the demand for abatement. It is important to note that by providing such hazard levels, EPA will not be eliminating the information costs altogether. For example, the costs of testing for levels of lead in soil, dust, and paint are still substantial. These are considered in this analysis. Also, any public information campaign to motivate households to be concerned about and test for lead contamination (analogous possibly to the public campaign currently being waged for radon) will impose costs. These have not been explicitly considered here.

The potential form of the hazard levels covers a wide range. At one extreme, the levels of action would be set uniquely for each individual home, taking its circumstances into account to determine whether soil, dust, and/or paint should be abated and, if so, how. At the other extreme, one hazard level would be set for each medium (soil, dust, and paint) for the entire nation. This analysis constructs different decision rules that reflect each of these extremes. A brief synopsis is provided here and greater detail in Chapter 6.

The first decision rule considered in this analysis has the highest information requirement. The public is assumed to have access to the same information that was used in this analysis (e.g., blood lead levels; reductions achievable from different abatements; the monetary values of these blood lead reductions; abatement costs; and the levels of lead in soil, dust, and paint and the condition of paint in the home). Having the highest information requirement has its rewards. Called the "voluntary optimum," this rule generates the highest net benefits of all decision rules evaluated since the information can be used to target abatement decisions so well.

By providing guidance to households in the form of hazard levels at which abatement should be undertaken, EPA can lower the actual information costs for the household abatement decision. In the other decision rules, households are assumed to have less information overall and therefore less leeway to choose on their own, instead being induced by EPA's hazard levels to initiate abatements of certain types. As a result, some households also make mistakes, such as abating when a benefit-cost analysis does not show that it is warranted or abating one medium, such as soil, when abating another, such as dust, would be more productive. It follows that the net benefits of these decision rules are not as high as those that can be achieved under the voluntary optimum, where more information is available. What these rules have in their favor though is their simplicity. The simpler the action levels, the less complicated is the decision for each household. If one or more action levels are exceeded, then a particular medium should be abated. At its simplest, one set of levels of action can be promulgated for the entire nation.

These decision rules are of four types, reflecting varying degrees. The first type of decision rule addressed paint condition. It assumes that all homes with non-intact paint will undertake paint abatement. The second type of decision rule included this criterion as well as a hazard level for each of the three media that are addressed by this rule - soil, dust, and paint. These are labeled "single-medium constrained" rules. The third type of decision rule encompasses hazard levels for two media, as well as condition. The fourth type of decision rule addresses all three media and condition. This analysis compares the net benefits of each of these decision rules for the abatements that are actually induced by the respective hazard levels.

3.4.2 Other Regulatory Options

Other regulatory instruments may also be effective for addressing the market failures that have led to inadequate abatement of lead. These alternative instruments have not been examined to the same extent as the primary instrument considered -information provision. Suggestions for alternatives that might be investigated further are provided in Exhibit 3-18. The list is meant to illustrative rather than exhaustive, particularly where economic incentives are concerned. The feasibility and advisability of these alternatives could vary widely.

Exhibit 3-18

Other Regulatory Alternatives

Type of Instrument	Possible Application
Labelling	Section 1018 of the Residential Lead-Based Paint Hazard Reduction Act of 1992 requires the disclosure of lead-based paint or any known paint hazards in the sale of target housing (any housing constructed prior to 1978). This provision could be extended to provide information on soil and dust hazards, not just paint, at the time of sale of <u>any</u> housing, not just target housing.
Technical and Performance Standards	Hazard levels could be enforced through performance or technical requirements. Owners of homes where children are present would, for example, have to keep paint in good condition, and reduce and keep soil and dust contamination below the hazard levels. Technical standards could specify exactly what abatements are necessary if hazard levels are exceeded.
Bans and Restrictions of Use	Restrictions could be placed on the access of young children to homes where lead contamination is of concern. These restrictions could include exclusion from occupying such homes or from spending extensive amounts of time in them, or prohibitions from accessing particular areas, such as rooms with paint in deteriorated condition or bare play areas outdoor where soil contamination is high.
Economic Incentives	A quota could be established for the numbers of homes allowed to have excess lead contamination. The quota could be allocated by a system of marketable allowances. Homes without allowances would have to undertake abatement or accept restrictions on their accessibility to young children.

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4. COSTS

4.1 METHOD FOR COST ANALYSIS

The general method used for the cost analysis was to develop a unit cost for the testing and abatement of lead in each medium (dust, paint and soil) for a single house and then apply this unit cost to the housing population to be abated. Abatements vary in effectiveness, duration and cost. To explore these variations, ten abatement strategy scenarios were considered along with the option not to abate. Abatements occurred just prior to the birth of the first child in a home. All cost results are presented in present value terms. Nominal costs from several studies have been used. Because of the narrow time range of the data around the base year (1987-1993 for a 1990 base year) and because the variation caused by changes in money value over time was within the uncertainty of the estimates, presenting the costs in constant dollars would have little effect. The next section describes the data available on the costs of testing and abatement for lead in dust, paint and soil. Section 4.3 shows a sample cost calculation and Section 4.4 presents results.

4.2 DATA

To carry out the analysis, unit costs for testing and high-end and low-end[1] levels of abatement of lead in dust, paint and soil were estimated from the available data. Primary sources of the data were the "Comprehensive and Workable Plan for the Abatement of Lead-Based Paint in Privately Owned Housing, Report to Congress" (HUD, 1990), the results from the Urban Soil Lead Abatement Demonstration Projects, and selected interviews with lead testing and abatement firms as well as landscapers, commercial cleaning services and hazardous waste disposal firms. The data were generally point estimates and in some cases represented costs for somewhat different services. For example, some estimates included relocation of the house occupants during abatement while others did not. Frequently the exact services included in a single estimate were not listed. This was particularly true of paint abatements where the information on the quantity of paint removed and the post-abatement testing were not clearly described. The analysis presents reasonable high and low cost estimates for each abatement scenario by combining the estimates obtained from these sources as described below. A medium value is also presented. In general this value is the mean of the high and low values.[2] The relative merits of each abatement depend not only on the costs of the abatement itself but also on its effectiveness and duration. Again information from the sources listed above were combined with the analyst's best judgment to create an estimate. These aspects of abatement (cost, effectiveness and duration) are discussed separately below for each medium. The costs

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1 The terms high-end and low-end refer to the level of abatement activity taking place. For each level high, medium and low costs have been estimated that reflects the range of costs for a particular activity level.

2 The only exception occurs for the medium exterior paint abatement cost. The $5,000 value used was based on abating a duplex and was considered more accurate than taking the mean of the high ($10,000 for a single family home) and low ($3,000 for a single unit of a multifamily dwelling) estimates.

of abating different media are then combined for each of the scenarios to provide a total cost for each abatement strategy.

4.2.1 Testing and Abatement Costs of Lead in Dust

Dust Testing

The few dust testing costs that have been reported in the literature are highly variable. This is probably due to differences in protocol such as the number of samples and the method of sampling. The Agency is in the process of developing its own dust testing standards. The current draft standards call for, at a minimum, collection of two dust samples in each of four rooms and additional samples if the paint is in poor condition. Further samples are required in common areas. Since there is no standard testing protocol, we combined the draft protocol with information obtained from lead abatement firms on the cost of testing. One reputable firm in New England reported a cost of inspection of \$128 (for paint,soil and dust) plus \$15 per sample analyzed (Ulluci, 1993). Combining one-third of the \$128 inspection cost with the testing costs of nine samples results in a \$178 dust testing estimate. The calculation is shown below.

$$0.33 \times \$128 + 9 \times \$15 = \$178 \qquad \text{Equation 4.1}$$

A further survey of three lead inspection firms in the Mid-west gave an average labor estimate of six hours per complete inspection of lead in paint, soil and dust at about \$40 per hour. The calculation for dust assumes that one third of that labor was needed to inspect for dust. A second estimate of the total cost of dust testing was calculated using this value for inspection and the mid-point of the range of sampling analysis costs, \$12-27, reported by nine Minnesota lead analysis firms. The resulting total testing cost, with ten samples required, is \$280 as shown below.

$$2 \times \$40 + 10 \times \$20 = \$280 \qquad \text{Equation 4.2}$$

Averaging the two calculated values (\$178 + \$280)/2 yields \$230 for an estimate of total dust testing costs.

The calculated testing estimates are very uncertain. The method used for sampling the dust was not recorded for any of the firms and could be an important cost factor. In addition, the values calculated were based on a limited review of the costs of testing. It is also likely that a range of quality coexists with the range of price and some quality control monitoring would be necessary in any dust testing scenario.

Dust Abatement

Cost. The cost of lead dust abatement depends on the thoroughness of the cleaning and whether rugs, furniture and duct work are replaced. Two sets of estimates are available. The first is from the Urban Soil Lead Abatement Demonstration Project cities which reported costs of \$134-458 in Boston (Weitzman et al., 1992) and \$1,216 in Cincinnati (Clark and Bornschein, 1993). The second is from the HUD Report to Congress which estimated a range of dust abatement costs from $505-730 per cleanup (HUD, 1990). For the high-end abatement option, the Cincinnati estimate was used as the high cost estimate while the mid-point of the Boston range, $300, was used as the lower value. The mean of the two was the medium cost value as shown in Exhibit 4-1. The abatement included moving families off-site while the floors, woodwork, window wells and some furniture were vacuumed with a high-efficiency particle accumulator vacuum. Hard surfaces were also wiped with a wet cloth following vacuuming.

The low-end dust abatement strategy is defined as an additional house cleaning, including general dusting, vacuuming, cleaning bathrooms and wiping window sills. The low cost estimate of $38 was based on an informal survey of cleaning services--an estimate of about $25 per hour for cleaning a 3-room apartment in an hour and a half (Rohmer, 1993). The high cost estimate was calculated assuming a six room house at the same hourly rate for a cost of $75 per cleaning. The medium cost estimate, $57, was the mean of the high and low cost values.

Effectiveness. The effectiveness of dust abatement depends on the circumstances in which it is used. A single cleaning, the nonrecurrent dust abatement scenario, will reduce the dust level to the lower of the dust level reported in the survey or the dust level calculated from the soil and paint lead levels as described in Chapter 3. Alternatively, recurrent dust abatement is assumed to reduce the dust lead level to 100 parts per million (ppm).

Duration. The duration of the dust abatement also depends on the circumstance in which it is used. If there are no external sources of lead the high-end dust abatement is assumed to be permanent. If there are external sources of lead the high-end dust abatement is assumed to be done every ten years and the low-end dust abatement is assumed to be done every month to maintain the abated level.

4.2.2 Testing and Abatement Costs for Lead-based Paint

Interior Paint Testing

The cost of testing for lead-based paint depends both on the type of testing done and the number of samples taken. The Agency is currently developing a testing protocol to standardize the number and type of tests required, and once the standards are finalized, variability based on these factors will be reduced. A typical testing plan requires a visual inspection of paint condition and determination of the lead content of painted surfaces by either *in situ* analysis using a portable x-ray fluorescence (XRF) spectrum analyzer or by off-site laboratory analysis of paint chip samples. X-ray fluorescence analysis has the advantage of being both lower in cost and non-destructive when compared with laboratory paint chip analysis. However, XRF readings are not as accurate as laboratory analysis (HUD, 1990).

Few paint testing costs are reported in the literature. The lead-based paint testing protocol for the Housing and Urban Development Department's 1989 lead in housing survey reported a $375 cost per unit (HUD, 1990). The cost included five interior readings and five exterior readings (using a portable XRF spectrum analyzer), a visual inspection, detailed estimation of the amount of paint surface and an interview with the owner. The $375 value

EXHIBIT 4-1

Summary of Abatement Costs for Lead in Dust[a]

Dust Abatement						
Activity Level	**Activities**	**Cost Estimate Level**	**Costs**		**Effectiveness**	**Duration**
			$ Value	**Source**		
High	Families moved off-site, hard surfaces (floors, woodwork, window wells and some furniture) vacuumed with a high-efficiency particle accumulator (HEPA) vacuum. Hard surfaces were also wiped with a wet cloth (an oil treated rag used on furniture) following vacuuming	High	$1,216 Recommend using $1200[b]	Clark et al., 1993	Estimated effectiveness varies based on scenario. For a single cleaning, the dust level is the lower of the HUD reported dust and that calculated for the soil and XRF levels. For recurrent cleanings, the dust level is reduced to 100 ppm.	Permanent if no lead source is present
		Medium	$750	Average of high and low		
		Low	$134-458 Recommend using $300[c]	Weitzman et al. 1992		
Low	One additional standard house cleaning per month including general dusting, vacuuming, cleaning bathrooms and wiping window sills	High	$75 Based on $25/hr for a 6 room house	Rohmer, 1993	(Only used as maintenance of the high-end dust abatement)	1 month
		Medium	$57	Average of high and low		
		Low	$38 1.5 hours for a 3 room apartment at $25/hour	Rohmer, 1993		

[a]Sources for cost estimates are listed in the fifth column of the table.
[b]Using only two significant figures for the estimate.
[c]Midpoint of the range rounded to two significant figures.

reported may thus overestimate the true value of interior lead-based paint testing alone because of the inclusion of detailed inspection and cataloging of the amount of paint present and the collection of exterior samples. A reputable contractor in New England quoted a price of \$55 for 25 XRF readings and \$128 for sample collection and travel as part of a complete lead inspection (Ullucci, 1993). If one-third of the collection and travel is attributed to the lead paint inspection (assuming soil and dust account for the remaining two-thirds) the total inspection and testing costs will be about \$100 as calculated below if 25 XRF readings are taken.

$$0.33 \times \$128 + \$55 \approx \$100 \qquad \text{Equation 4.3}$$

As mentioned in Section 4.2.1, a survey of three lead inspection firms in the Mid-west gave an average labor estimate of a six hours per complete inspection of lead in paint, soil and dust at about \$40 per hour. This information was combined with sample analysis costs from a list of Minnesota de-leading contractors (primarily from the Minneapolis/ St. Paul area) that showed a range of lead paint sample analysis costs of \$18-27 per sample. An estimated lead testing cost of \$360 per house was calculated by assuming that sampling costs are \$23, the mid-point of the range, and that twelve samples were taken and analyzed (based on a protocol of two per room for four rooms as is likely in the EPA protocol and four in the entryways or common areas). In addition, it was assumed that lead paint sampling labor is one-third of the total inspection labor. The value is calculated below.

$$2 \times \$40 + 12 \times \$23 \approx \$360 \qquad \text{Equation 4.4}$$

Our final estimated cost of \$230 is the average of the estimated costs from the New England and Minnesota data, (\$100 + \$360)/2 = \$230. The HUD cost value was not included because of the additional cataloging and interviewing it involved. Lead abatement inspections are still in their infancy and with more competition, the price could be lowered; however, as standards are instituted, the price may rise because of training costs and performance requirements. In addition, if the lead paint testing is not carried out in conjunction with inspections of other media, the cost of travel and collection could rise. The variation in costs is likely to be large given the range of house sizes and the possible variation in the number of samples taken.

Exterior Paint Testing

The cost of testing for exterior lead-based paint was estimated at \$115, half the value of the interior lead-based paint testing. Because exterior lead-based paint covered surfaces tend to be larger and less varied than interior surfaces, fewer samples would probably be needed to establish the extent of lead-based paint. In this analysis it is assumed that half as many samples are taken outside as are taken inside. Six samples are taken, one for each of the four sides of a house and two for added features such as porches and doors, so the sampling time and testing costs should be approximately half the value of interior lead-based paint testing which requires twelve samples. Four environmental lead analysis firms were contacted to confirm the two to one ratio of interior to exterior paint testing. Only two of the firms conduct this type of testing on private homes and both use a ratio of approximately two-to one. Gene Sparrow of Advanced R&D, St. Paul, Minnesota takes about 12 interior samples and between 4 and 8 exterior samples. Scott Askew of Nova Environmental Services, Incorporated takes 15-20 samples inside and 7-8 samples outside.

Interior Paint Abatement

Cost. Similar to the cost of testing, the estimated cost of interior lead paint abatement can vary widely. Some of the variation is caused by differences in the extent of abatement. For example, replacing the windows is less expensive than removing all the molding, doors and wall paint. Some of the variation is due to the size of the house and some is due to regional cost variation. The average cost reported by local abatement programs for lead abatement is $2,100 in 1989 dollars, according to a Center for Disease Control (CDC) report based on local projects that included abatement of common areas and exterior when necessary, costs of materials, labor insurance, overhead, worker protection and cleanup (CDC, 1991). The estimated costs in the HUD Report to Congress are much higher, except in the "Units with Interior Lead-Based Paint (LBP) Only" category, which estimates $1,808 per unit of removal. HUD also found that over 50 percent of all housing units with lead-based paint could be abated by removal for under $2,500 per unit. The Boston Globe reported the average cost of a de-leading job for a single unit in Massachusetts as $3,450 in 1990 where valid methods of abatement include stripping, removal or enclosure of the lead paint (Carroll, 1993). Based on the values for interior paint abatement estimated in a Michigan grant proposal to the CDC, the complete abatement cost estimates range from $16,000 per unit for a ten unit apartment building to $23,000 per unit for a single family house. The proposal also reports an average cost of $15,000 for units abated by Maryland and Minnesota under their state plans. No distinction is made on this last value between interior and exterior lead-based paint abatement. Telephone calls to a small sample of de-leading contractors in the United States produced a range of estimates from $4,000 to $12,000 for a complete interior lead paint abatement. As part of the Boston study of the effects of soil abatement, 46 homes were de-leaded with a reported average cost of $7,500 for interior paint de-leading. If the costs of moving, storage, alternative housing, inspections, monitoring and clearance samples are added, the costs could rise to $10,000-$10,500 (Weitzman, 1992). A typical interior lead-based paint abatement in Maryland was reported to be about $12,000 although there is considerable variation (Morris, 1993). Exhibit 4-2 summarizes the various cost estimates for interior paint abatement.

The high-end paint abatement option for our model is complete removal of lead-based paint including full abatement of windows, doors, woodwork and walls plus a high-end dust abatement. The range of abatement costs presented above reflects differences in house size, quantity of lead paint present and abatement technique used. For this analysis we developed high, medium and low costs for the high-end abatement activities. Typical low cost for high-end abatement was $7,500 while $12,000 was considered representative of recent high cost experience in complete interior lead paint removal including disposal of debris as a non-hazardous waste (excluding dust abatement). The medium cost ($9,750) reflects the mean of high and low values for high-end paint abatement. If dust abatement (Section 4.2.1) is included, the total low, medium, and high cost high-end paint abatements are $8,250, $10,500, and $12,750 respectively. High-end dust abatement is included in this calculation to ensure that the full abatement effectiveness is achieved. These values are shown in Exhibit 4-3.

While complete removal of all lead paint represents a high-end abatement, replacement of windows reflects a typical partial abatement. Paint on windows is preferentially prone to peeling and flaking due to movement of the sash and the increased exposure to sunlight and weathering. The cost of replacing a window ranges from $131 for an aluminum window to $262 for a wooden sliding window (R.S. Means, 1987). An informal interview with Vance Morris of Maryland's Department of Housing and Community Development confirmed $200 as an average value for a window replacement (Morris, 1993). Information on the average number of windows per house is difficult to obtain since this

EXHIBIT 4-2

Summary of Interior Lead-based Paint Abatement Costs

Cost	Activities Covered	Source
$1,808	Removal of lead-based paint in units with only interior lead-based paint	HUD, 1990
$2,100	Average lead abatement cost reported by local abatement programs	CDC, 1991
$2,500	Value at which 50% of all housing units with lead-based paint could be abated by removal	HUD,1990
$3,450	Average cost of a de-leading job for a single unit in Massachusetts in 1990 by stripping, removal or enclosure	Carroll, 1993
$4000-$12,000	Complete lead abatement, method unspecified	Sample of U.S. de-leading contractors
$7,500	Average cost of de-leading 46 homes in Boston	Weitzman, 1992
$10,000-$10,500	Average cost of de-leading 46 homes in Boston if moving, storage, alternative housing, inspections, monitoring and clearance samples are added	Weitzman, 1992
$12,000	Typical interior lead-based paint abatement in Maryland, method unspecified	Morris, 1993
$15,000	Stated as average cost for unit abated in Maryland and Minnesota, may include exterior paint abatement as well	Michigan, 1991
$16,000 per unit for a ten unit apartment $23,000 for a single family house	Interior lead-based paint abatement cost estimates	Michigan, 1991

EXHIBIT 4-3
Summary of Abatement Costs for Lead in Paint[a]

Interior Lead-Based Paint Abatement						
Activity Level	**Activities**	**Cost Estimate Level**	**Costs**		**Effectiveness**	**Duration**
			$ Value	**Source**		
High	Full abatement of windows, doors, woodwork and walls, includes mean high-level dust abatement necessary to ensure abatement to effectiveness level postulated values do not include disposal of abatement debris as a hazardous waste	High	Elements: $12,000[b] + $750[c] Total: $12,750	Morris, 1993	Abated to a paint lead level corresponding to removal of all paint plus removing all the paint ingestion for pica children	Permanent
		Medium	Elements: $9,750[d] + $750[c] Total: $10,500	Average of high and low estimates		
		Low	Elements: $7,500[e] + $750[c] Total: $8,250	Weitzman, 1992		
Low	Replace 15 windows @ $200 each plus mean high-level dust abatement to ensure abatement to effectiveness postulated	High	Elements: $3,000[f] + $750[c] Total: $3,750	Morris, 1993	Abated to a dust lead level that is 91.4% of the original dust level plus removing all the paint ingestion for pica children (See Section 4.2.2)	Permanent (for windows)
	Replace 10 windows @ $200 each plus mean high-level dust abatement to ensure abatement to effectiveness postulated	Medium	Elements: $2,000[g] + $750[c] Total: $2,750			
	Replace 5 windows @ $200 each, plus mean high level dust abatement to ensure abatement to effectiveness postulated	Low	Elements: $1000[h] + $750[c] Total: $1,750			

[a] Sources for cost information are shown in the fifth column of the table.
[b] High-cost estimate for High-end interior lead-based paint abatement.
[c] Average-cost estimate for High-end lead dust abatement.
[d] Medium-cost estimate for High-end interior lead-based paint abatement.
[e] Low-cost estimate for High-end interior lead-based paint abatement.
[f] High-cost estimate for Low-end interior lead-based paint abatement.
[g] Medium-cost estimate for Low-end interior lead-based paint abatement.
[h] Low-cost estimate for Low-end interior lead-based paint abatement.

information is included in neither the American Housing Survey nor the decennial census. The low, medium and high estimates were calculated using 5, 10, and 15 windows[3], respectively; the resulting overall cost estimates of low-end paint abatement are $1000, $2,000 and $3,000. Including high-end dust abatement brings the totals to $1,750, $2,750, and $3,750. The equation is shown below.

$$LPAC = W \times \$200 + \$750 \qquad \text{Equation 4.5}$$

where:

LPAC = Low-end Paint Abatement Cost, and
W = Number of windows.

The Michigan proposal estimates a value of between $3000 and $6500 for replacement of windows in one unit of a ten unit apartment and a single family dwelling, respectively. The lower costs are used for the modelling effort with the understanding that the actual value could vary greatly depending on the type and number of windows replaced. These values do not explicitly assume debris disposal costs but if the waste is considered non-hazardous its disposal cost is within the uncertainty of the cost estimate. The Agency has not yet made a decision on whether paint abatement waste will be exempted from the Resource Conservation and Recovery Act hazardous waste definitions. Under current regulation, only those portions of the waste that fail the Toxicity Characteristic Leaching Procedure (TCLP) for lead are considered hazardous waste.[4] Disposal costs depend on the quantity being discarded. If each abatement produced an average of 217 pounds of hazardous waste, as was generated per housing unit in the Housing and Urban Development abatement demonstration project, and cost the reported $255 to discard, the paint abatement costs would increase between two and nine percent depending on whether the low-end or high-end abatement scenario was chosen (US EPA, 1992a).

Effectiveness. The removal of all the lead-based paint in a home (the high-end paint abatement option) was assumed to have an effectiveness equivalent to eliminating the paint contribution to lead dust as well as removing the possibility of high blood lead levels resulting from pica (the consumption of non-food items). However, little data are available regarding the effectiveness of abatement techniques. The HUD demonstration study did conduct follow-up on lead paint abatement effectiveness but the

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[3] Personal communication with Gopaul Ahluwalia at the National Association of Home Builders, 1993. Mr. Ahluwalia estimated the average number of windows in a new single family home (17) and the average number per unit in a new multifamily apartment building (9) based on a recent construction-material-usage data base. There are two trends in home building that need to be considered before using these estimates as the number of windows present in homes built prior to 1980 (our population of interest for lead abatement). The first is that new homes are larger now than in the past and second, homes are currently built with more windows to increase light in the house. No quantitative information was available about the latter trend but the former trend was compensated for by multiplying the 1993 average number of windows by the ratio of the average square feet per single family home in 1980 compared to that estimated for 1993 (1600 sq. ft./2100 sq. ft.) resulting in an estimate of 13 windows per average single family home and 7 windows per unit for a multifamily dwelling built in 1980. The range investigated in the model 5-15 brackets these estimates. Obviously, very large single family homes can have many more windows than the reasonable high value of 15 used in this analysis.

[4] Personal communication with Rajani Joglekar, Office of Solid Waste and Emergency Response, US EPA, 1993.

resulting values are reported as dust lead loadings which are not directly translatable into the dust lead concentration values used in our model.

Window replacement was estimated to contribute 8.6 percent of the benefits that would accrue from abatement by removal. The dust level is directly tied to the benefits thus the post window abatement dust level is 91.4 percent (100 - 8.6 percent) of the original dust level. This value was based on a calculation from the HUD survey data that showed about 8.6 percent of the lead-based paint accessible to children was on windows. This value may underestimate the effectiveness of the abatement in homes where only the windows have lead-based paint or contribute to the lead dust levels. However, the value may overestimate the effectiveness in houses with a large amount of accessible lead paint in places other than windows. In addition, the threat of elevated blood lead levels due to pica was removed from homes that had window replacement.

Duration. Removal of lead-based paint from a house results in permanent abatement as long as all the paint was removed as postulated in the high-end option. There should be no further lead contribution from interior paint under this option. In the low-end option where the windows were replaced, there is also permanent removal of a portion of lead-based paint. Thus, the overall assumption is permanent duration of paint abatement.

Exterior Paint Abatement

Cost. The cost of exterior lead-based paint abatement depends on many factors including the size of the house, whether or not the dwelling is a multi-unit abode and the method of abatement. The estimates for low, medium and high costs were obtained from the Michigan report. The report listed costs of re-siding for a unit of an apartment complex, a duplex, and a single family home, as $3,000, $5,000 and $10,000 respectively; these values were taken as low, medium and high exterior paint abatement cost estimates (Michigan, 1991). The HUD Report to Congress shows exterior abatement costs for homes that have only exterior lead-based paint as $2,841 for encapsulation and $4,791 for removal. However, if the costs quoted in HUD for abating interior lead-based paint are subtracted from the costs of abating units with both interior and exterior lead-based paint, the cost of abating exterior lead-based paint is estimated to be $6,600. While the latter value may overestimate the cost because some of the difference may be due to increased interior lead-based paint abatement costs, it reflects some of the variation among homes. The Boston experience with de-leading the interiors of 46 homes, as reported in Weitzman, is $5,700 per home (Weitzman, 1992). These values confirm the range of values chosen as our estimates.

Effectiveness. Abatement of exterior lead-based paint in this analysis is used only to ensure that the soil abatement effectiveness projected below (in Section 4.2.3) is achieved. As a consequence, the effectiveness is not independent of the soil abatement value. However the contribution of exterior lead-based paint to soil has been assumed to be eliminated by the abatement as described in Exhibit 4.4.

Duration. Exterior lead-based paint abatement is assumed to be permanent because all paint has been removed.

4.2.3 Testing and Abatement Costs of Lead in Soil

Soil Testing

As with paint, soil testing costs can vary considerably based on the number of samples taken, the method of analysis used and the region of the country. The cost of soil sampling reported by Baltimore in the Urban Soil Lead Abatement Demonstration Project is $825 for the 30 samples that were taken and analyzed for each house (Farrell, 1993). The HUD survey took only nine samples per house but did not report the cost of sampling (HUD, 1990). The Agency is in the process of developing a standardized testing protocol. For the purposes of this study a four sample protocol was adopted, based on two composite dripline samples and two play area samples. If there is more than one play area, then the sampling cost would rise. Estimated costs are based on two data sources. The first is a reliable lead contracting firm in New England that provided information indicating that each soil sample analysis costs $16 and overall inspection costs $128 for paint, lead and soil (as discussed in Section 4.2.1). By assuming that one-third of the inspection time is devoted to soil sampling and assuming four soil samples are taken, the soil testing costs are about $106 as shown below.

$$0.33 \times \$128 + 4 \times \$16 = \$106 \qquad \text{Equation 4.6}$$

The second data source is a list of laboratories and consultants in Minnesota that provide environmental lead analysis. This list shows a range of $12-32 for sample analysis costs. Assuming two hours of labor (at $40 per hour) for inspection and sampling of soil, and analysis of four samples at $22 each, (the mid-point of the range), an estimate of $170 for soil testing results is calculated below.

$$2 \times \$40 + 4 \times \$22 \approx \$170 \qquad \text{Equation 4.7}$$

We used the average of the two calculated values, ($106+170)/2 = $138, as the soil testing cost. The sampling for Baltimore was not included in the estimate because we lacked information on how the analysis was conducted. However, the wide range of the estimates suggests that further investigation may be warranted.

Soil Abatement

Cost. The costs of soil abatement are tied to the area treated, the method used and whether or not the waste is considered hazardous under the Resource Conservation and Recovery Act (RCRA). Residential soil abatement is a relatively new industry and no standards have been established on what constitutes a complete abatement. The three participants in the Urban Soil Lead Abatement Demonstration Project, (Boston, Baltimore, and Cincinnati) provided costs for a high-end abatement process. The procedure involved removal of six inches of top soil, installation of a barrier (Boston only), disposal of the contaminated soil as non-hazardous waste and replacement with new soil with less than 150 ppm lead (or less than 50 ppm in Baltimore and Cincinnati) (Elias, 1993). The costs ranged from $2,400 per property in Cincinnati, to $4,896 per property in Baltimore, to $6,600 and $9,600 per property under two separate contracts in Boston (Elias, 1992). The higher of the two Boston studies was chosen as the high representative of the costs of high-end residential soil abatement because of the use of the barrier. Because simultaneous dust abatement is necessary to achieve full effectiveness for soil abatement, this value was combined with the high-end dust abatement cost, described in Section 4.2.1, for a total of $10,350. The lower cost estimate used the Baltimore value of $4,896, which, including high-end dust abatement sums to $5,646. The Baltimore study was preferred in this instance to the Cincinnati study because the latter study primarily abated playgrounds rather than residential lawns. Exhibit 4-4 summarizes the soil abatement cost information.

In certain cases, three other costs were added to the high-end soil abatement. The first is the cost of exterior paint abatement if the house has an exterior XRF reading greater than 1 mg/cm^2. The exterior paint abatement costs have been described above. Because exterior lead-based paint is a primary source of lead soil contamination, it is necessary to abate the exterior paint to maintain the low soil lead levels achieved by soil abatement. Two additional costs are incurred if the soil must be transported and disposed as a hazardous waste under RCRA. Soil is considered hazardous if it fails the Toxicity Characteristic Leaching Procedure (TCLP) for lead. Many factors affect the leaching characteristics of lead in soil including the soil type and pH. As a conservative estimate we assumed soil with lead levels greater than 2000 ppm will fail the test. Thus houses with soils that fail the TCLP will incur the additional soil disposal and transportation costs. Based on an interview with Chemical Waste Management the cost of stabilization and landfilling of lead contaminated soil is between $230 and $275 per ton (Donegan, 1993).

The high cost option uses the quantity of soil removed from lawns under the 1989 Boston contract (41 cubic yards) (Weitzman, 1992). The soil abatements from the Demonstration Project already include the cost of disposing of the soil as a non-hazardous waste. To avoid double counting the disposal the cost of $250 per ton for hazardous waste was reduced by $35 per ton for landfilling non-hazardous waste, which results in a cost of $215 per ton. The $215 per ton is multiplied by 41 cubic yards and by 1.3 tons per cubic yard for a total disposal cost of $11,460. For the lower cost estimate, the Baltimore experience of an average of 14.2 cubic yards of soil removed per lawn was used; this resulted in disposal costs of $3,968 (Farrell, 1992). A sample calculation is shown below.

$$14.2\ yd^3\ x\ 1.3\ \frac{ton}{yd^3}\ x\ \$215\ per\ ton\ =\ \$3{,}968 \qquad \text{Equation 4.8}$$

A typical transportation cost for hazardous waste is $425 per 22 ton dump truck for under 100 miles (Donegan, 1993). Assuming the truck is full and that the disposal site is within 100 miles the cost is $425/22 tons equalling $19.32 per ton. This is $19.32 times 41 cubic yards times 1.3 tons per cubic yard, equalling $1,040 for the high end cost. A sample calculation is shown below.

$$\$19.31\ per\ ton\ x\ 14.2\ yd^3\ x\ 1.3\ \frac{ton}{yd^3}\ \approx\ \$360 \qquad \text{Equation 4.9}$$

The low-end abatement is a resodding of the lawn. The critical determinant of this cost is the area resodded. The high-end estimate was calculated using the average size of lawn abated in the Boston experience of the Urban Soil Lead Abatement Demonstration Project, equal to 2,141 square feet. The average cost of resodding, including preparing the ground and applying the sod but not removing

EXHIBIT 4-4
Summary of Abatement Costs for Lead in Soil[a]

Soil Abatement							
Activity Level	Activities	Cost Estimate Level	Costs			Effectiveness	Duration
			$ Value		Source		
High	Removal of 6 inches of top soil, barrier installed and new soil (tested at under 150 ppm) used as a replacement, resodding plus high-end dust abatement, plus hazardous waste disposal of soil >2000 ppm plus the transportation costs for disposing of hazardous soil.	High	>2000 ppm	≤2000 ppm	Weitzman, 1992 for soil abatement protocol, Elias, 1993 for soil abatement cost and Donegan, 1993 for hazardous waste disposal and transportation costs and Michigan, 1991 for exterior lead-paint abatement	Soil is abated to 100 ppm	Permanent
			Elements[b]: $9,600 + $750 + $11,460[d] + $1,040 + $10,000 (Only if exterior paint is present) Total: $22,850 + $10,000 (Only if exterior paint is present)	Elements[c]: $9,600 + $750 + $10,000 (Only if exterior paint is present) Total: $10,350 + $10,000 (Only if exterior paint is present)			
	Average of High and Low Costs	Medium	>2000 ppm	≤ 2000 ppm	Average of high and low values for soil abatement and Michigan, 1991 for exterior paint abatement costs		
			Elements[e]: $7,248 + $750 + $7,714[d] + $700 + $5,000 (Only if exterior paint is present) Total: $16,412 + $5,000 (Only if exterior paint is present)	Elements[f]: $7,248 + $750 + $5,000 (Only if exterior paint is present) Total: $7,998 + $5,000 (Only if exterior paint is present)			
	As above without the barrier and using the Baltimore cost of abatement plus dust abatement plus 10.9 cubic meters (14.2 cu.yd) soil removed	Low	>2000 ppm	≤2000 ppm	EPA, 1993 for amount of soil and Elias, 1993 for cost of soil abatement and Donegan, 1993 for cost of disposal and transport of hazardous waste and Michigan, 1991 for exterior paint abatement costs		
			Elements[g]: $4,896 + $750 + $3,968[d] + $360 + $3,000 (Only if exterior paint is present) Total: $9,974 + $3,000 (Only if exterior paint is present)	Elements[h]: $4,896 + $750 + $3,000 (Only if exterior paint is present) Total: $5,646 + $3,000 (Only if exterior paint is present)			

EXHIBIT 4-4
Summary of Abatement Costs for Lead in Soil[a]

Soil Abatement						
Activity Level	Activities	Cost Estimate Level	Costs		Effectiveness	Duration
			$ Value	Source		
Low	Resodding 2,141 square feet @ $1.45/square foot plus mean high-end dust abatement Activities include resodding a little grading but no removal of existing grass	High	Elements[i]: $3,104 + $750 Total: $3,854	Weitzman, 1992 for size of lawn and Degen, 1993 for cost of resodding	Soil is abated to 500 ppm	5 years
	Average of high and low	Medium	Elements[j]: $2,110 + $750 Total: $2,860	Average of high and low		
	Resodding 770 square feet @ $1.45/square foot plus mean high-end dust abatement (10.9 cu.m. per property x 35.3 cu ft/cu.m at 6")	Low	Elements[k]: $1,116 + $750 Total: $1,866	EPA, 1993 Baltimore experience for size of lawn and Degen, 1993 for cost of resodding		

[a] Sources are listed in the sixth column of the table.
[b] $9,600 = High-cost/High-end soil; $750 = Average-cost/High-end dust; $11,460 = High-cost soil disposal; $1,040 = High-cost transport; $10,000 = High-cost exterior lead paint abatement.
[c] $9,600 = High-cost/High-end soil; $750 = Average-cost/High-end dust; $10,000 = High-cost exterior lead paint abatement.
[d] Assumes removal of 6 inches and is the difference of hazardous waste disposal and regular landfilling since the Urban Soil Lead Abatement Demonstration Project values include soil disposal
[e] $7,248 = Medium-cost/High-end soil; $750 = Average-cost/High-end dust; $7,714 = Medium-cost soil disposal; $700 = Medium-cost transport; $5,000 = Medium-cost exterior lead paint abatement.
[f] $7,248 = Medium-cost/High-end soil; $750 = Average-cost/High-end dust; $5,000 = Medium-cost exterior lead paint abatement.
[g] $4,896 = Low-cost/High-end soil; $750 = Average-cost/High-end dust; $3,968 = Low-cost soil disposal; $360 = Low-cost transport; $3,000 = Low-cost exterior lead paint abatement.
[h] $4,896 = Low-cost/High-end soil; $750 = Average-cost/High-end dust; $3,000 = Low-cost exterior lead paint abatement.
[i] $3,104 = High-cost/Low-end soil lead abatement; $750 = Average-cost/High-end dust abatement.
[j] $2,110 = Medium-cost/Low-end soil lead abatement; $750 Average-cost/High-end dust abatement.
[k] $1,116 = Low-cost/Low-end soil lead abatement; $750 = Average-cost/High-end dust abatement.

existing sod, is about $1.45 per square foot based on informal interviews with landscapers. The total high cost is thus $3,104. The low estimate of $1,116 is calculated using the same cost per square foot applied to the average size of the lawn abated in Baltimore (770 square feet); this area was calculated based on the amount of soil removed. The medium estimate is the mean of the high and low estimates. Including dust abatement, the totals are $3,854, $2,860, and $1,866 as shown in Exhibit 4-4. The high cost estimate is shown below as a sample calculation.

$$\$1.45 \times 2{,}141\ ft^2 + \$750 = \$3{,}854 \qquad \text{Equation 4.10}$$

These estimates may be low compared to resodding an entire suburban lawn of 2,500 to 7,000 square feet (a typical size range) but may represent a realistic value if only a portion of the lawn is resodded. In addition, the cost of resodding can vary based on the physical layout of the property. For example, if trees are present, additional labor will be required to sod around such obstacles raising the $1.45 per square foot estimate.

Effectiveness. The high end abatement is assumed to reduce the soil lead level to 100 ppm, the average of the lead levels in the replacement soil in the Urban Soil Lead Abatement Demonstration Project (US EPA, 1993). The low-end estimate for the effectiveness of resodding is 500 ppm since in the past, the Agency has used this value as an action level. No measurements of the effectiveness of resodding were found.

Duration. The high-end soil abatement is permanent as long as there are no external sources of lead. The low-end abatement (resodding) was assumed to last five years based on expectations of sod durability obtained from landscaping firms in an informal survey.

Effect of Bare Soil on Soil Abatement Cost Scenarios. The cost of the high-end soil abatement scenario may be slightly higher for covered soil than for bare soil if extra sod must be removed from the yard; the low-end soil abatement may not be needed at all if the sod covering the soil is intact. The effectiveness of the two abatement scenarios as measured by the post-abatement soil lead level is unaffected by the initial condition although resodding would not achieve significant reduction in exposure if the soil were already covered. Initial soil coverage conditions would have no affect on the abatement duration. As mentioned in Chapter 3, data limitations make us unable to specifically address bare and covered soils. Qualitative discussions of the implications of this limiation for the benefit and benefit-cost results are contained in Chapters 5 and 7.

4.2.4. Combined Abatement Scenario Costs

Exhibits 4-1 through 4-4 showed the costs of abatements in each medium. These abatements were combined into ten plausible scenarios that are summarized in Exhibits 4-5 and 4-7 below. In practice there will be considerable variation in the costs. A formal survey of current lead abatement practice could provide better estimates of the true costs; in addition, a controlled study could provide better data on the effectiveness and duration of the abatement techniques. In further work, a sensitivity analysis is planned to address the uncertainty in these estimates. The exhibits show the ten abatement strategies analyzed in this report (the eleventh "no abatement" has no cost) and the lifetime cost of the strategy in the year of abatement. A seven percent discount factor was used to calculate the net present values. The values are presented in Exhibits 4-5 and 4-6. The calculation of abatement costs that occur over the homes' lifetime, low-end soil and recurrent dust, were further discounted by 0.5% per year to account for the removal of homes from the housing stock.

Because damages to children occur only through age seven in the main model analysis, abatement should only occur when a child under the age of seven is resident in the home. The values used here include all years, once an abatement is undertaken. This provides an accurate estimate for those abatements that are permanent but it overestimates the cost of recurrent abatements because the abatement activity, such as resodding, should only occur when a child under seven is resident.

4.2.5 Enforcement Costs

There are no enforcement costs associated with Section 403. Section 403 requires that the Agency set hazard levels for lead in paint, soil and dust that will be used in other sections of Title X to trigger abatements. The enforcement costs of these actions, however, are not attributable to Section 403 but to the section of the rule requiring the abatement. All abatement activity under Section 403 is voluntary and thus incurs no enforcement cost.

4.2.6 Implementation Costs

The implementation costs associated with Section 403 are of two types. The first is the cost of setting and promulgating the Section 403 hazard levels themselves; a negligible cost compared to the funding appropriated in Title X for abatement ($250 million in 1994). The second implementation costs would be those of states or localities that voluntarily use the hazard levels set by the Agency as action levels in their own lead management programs. The size of these costs depend on the current level of activity at the state and local level, whether the hazard levels the Agency sets are above or below those of the programs in place, and the number of programs that implement the hazard levels. If the Agency levels are more stringent than current practice, implementation costs could be significant; however if the Agency levels are higher than those in practice implementation costs will be negligible. No quantitative evaluation of the implementation costs was attempted because reliable information on current and expected future programs at the state and local level was not available. If implementation costs are proportional to the number of homes affected, which could be the case if state or local authorities decided to track homes to assure abatement, then the inclusion of implementation costs in the benefit-cost analysis would favor higher hazard levels over lower ones, all other things equal, since the number of homes to be tracked would be lower under the latter than the former.

EXHIBIT 4-5

Summary of Unit Abatement Costs by Scenario

Single Media Abatement Scenarios	Activities	Unit Cost
High-end Paint Abatement	Paint abatement and dust abatement	High Estimate - $12,750 Medium Estimate- $10,500 Low Estimate- $8,250
Low-end Paint Abatement	Window abatement and dust abatement	High Estimate - $3,750 Medium Estimate- $2,750 Low Estimate - $1,750
Non-Recurrent Dust	One high-end dust abatement	High Estimate - $1200 Medium Estimate - $750 Low Estimate - $300
Recurrent Dust	High-end dust every 10 years, Low-end dust monthly	Ten year / Monthly / Total Cost Estimate[5] High / High / $14,621 High / Low / $8,524 Low / High / $12,925 Low / Low / $6,828 Medium / High / $13,773 Medium / Low / $7,676
High-end Soil Abatement	Complete removal and replacement of soil (includes disposal and transportation of hazardous waste for concentrations above 2000 ppm and also exterior paint abatement with additional cost for those houses with exterior paint)	High cost >2000 ppm and exterior paint - $32,850 ≤2000 ppm and exterior paint - $20,350 >2000 ppm and no exterior paint - $22,850 ≤2000 ppm and no exterior paint - $10,350 Medium cost >2000 ppm and exterior paint - $21,412 ≤2000 ppm and exterior paint - $12,998 >2000 ppm and no exterior paint - $16,412 ≤2000 ppm and no exterior paint - $7,998 Low cost >2000 ppm and exterior paint - $12,974 ≤2000 ppm and exterior paint - $8,646 >2000 ppm and no exterior paint - $9,974 ≤2000 ppm and no exterior paint - $5,646
Low-end Soil Abatement	Resod every 5 years, High-end dust abatement at first resodding	High[5] - $10,669 Medium[5] - $7,493 Low[5] - $4,316

[5] Includes discounting at 7% to the year of abatement and removal of housing stock at a 0.5% rate. (Total cost would be further discounted to 1994.)

EXHIBIT 4-6

Summary of Combined Abatement Strategies

Net Present Value Costs for Combined Scenarios				
Scenario	**Cost Elements**		**Unit Costs - Discounted at 7 percent to the year of abatement**	
High-end Paint and High-end Soil	>2000 ppm	≤2000 ppm	>2000 ppm	<2000 ppm
	High[a] $12,000 + $750 + $9,600 + $750 + $11,460 + $1,040 + $10,000 (Only if exterior paint is present)	High $12,000 + $750 + $9,600 + $750 + $10,000 (Only if exterior paint is present)	High $35,600 +$10,000 (Only if exterior paint is present)	High $23,100 + $10,000 (Only if exterior paint is present)
	Medium[b] $9,750 + $750 + $7,248 + $750 + $700 + $7,714 + $5,000 (Only if exterior paint is present)	Medium $9,750 + $750 + $7,248 + $750 + $5,000 (Only if exterior paint is present)	Medium $26,912 + $5,000 (Only if exterior paint is present)	Medium $18,498 + $5,000 (Only if exterior paint is present)
	Low[c] $7,500 + $750 + $4,896 + $750 + $3,968 + $360 + $3,000 (Only if exterior paint is present)	Low $7,500 + $750 + $4,896 + $750 + $3,000 (Only if exterior paint is present)	Low $18,224 + $3,000 (Only if exterior paint is present)	Low $13,896 + $3,000 (Only if exterior paint is present)
High-end Paint and Low-end Soil	High[d] $12,000 + $750 + $10,669		High $23,419	
	Medium[e] $9,750 + $750 + $7,493		Medium $17,993	
	Low[f] $7,500 + $750 + $4,316		Low $12,566	

[a] $12,000 = High-cost/High-end interior lead paint abatement; $750 = Average-cost/High-end dust abatement; $9,600 = High-cost/High-end soil lead abatement; $750 = Average-cost/High-end dust abatement; $11,460 = High-cost hazardous soil disposal; $1,040 = High-cost soil transport; $10,000 = High-cost exterior lead paint abatement.

[b] $9,750 = Medium-cost/High-end interior lead paint abatement; $750 = Average-cost/High-end dust abatement; $7,428 = Medium-cost/High-end soil lead abatement; $750 = Average-cost/High-end dust abatement; $7,714 = Medium-cost hazardous soil disposal; $700 = Medium-cost soil transport; $5,000 = High-cost exterior lead paint abatement.

[c] $7,500 = Low-cost/High-end interior lead paint abatement; $750 = Average-cost/High-end dust abatement; $4,896 = Low-cost/High-end soil lead abatement; $750 = Average-cost/High-end dust abatement; $3,968 = Low-cost hazardous soil disposal; $360 = Low-cost soil transport; $3,000 = Low-cost exterior lead paint abatement.

[d] $12,000 = High-cost/High-end interior lead paint abatement; $750 = Average-cost/High-end dust abatement; $10,669 = High-cost/Low-end soil with resod every 5 years and High-end dust abatement at first resodding (see Exhibit 4-5).

[e] $9,750 = Medium-cost/High-end interior lead paint abatement; $750 = Average-cost/High-end dust abatement; $7,493 = High-cost/Low-end soil with resod every 5 years and High-end dust abatement at first resodding (see Exhibit 4-5).

[f] $7,500 = Low-cost/High-end interior lead paint abatement; $750 = Average-cost/High-end dust abatement; $4,316 = High-cost/Low-end soil with resod every 5 years and High-end dust abatement at first resodding (see Exhibit 4-5).

EXHIBIT 4-6

Summary of Combined Abatement Strategies

Net Present Value Costs for Combined Scenarios				
Low-end Paint and High-end Soil	>2000 ppm	≤2000 ppm	>2000 ppm	≤2000 ppm
	High[g] $3,000 + $750 + $9,600 + $750 + $11,460 + $1,040 + $10,000 (Only if exterior paint is present)	High $3,000 + $750 + $9,600 + $750 + $10,000 (Only if exterior paint is present)	High $26,600 + $10,000 (Only if exterior paint is present)	High $14,100 + $10,000 (Only if exterior paint is present)
	Medium[h] $2,000 + $750 + $7,248 + $750 + $7,714 + $700 +$5,000 (Only if exterior paint is present)	Medium $2,000 + $750 + $7,248 + $750 + $5,000 (Only if exterior paint is present)	Medium $19,162 + $5,000 (Only if exterior paint is present)	Medium $10,748 + $5,000 (Only if exterior paint is present)
	Low[i] $1,000 + $750 + $4,896 + $750 + $3,968 + $360 + $3,000 (Only if exterior paint is present)	Low $1,000 + 750 + $4,896 + $750 + $3,000 (Only if exterior paint is present)	Low $11,724 + $3,000 (Only if exterior paint is present)	Low $7,396 + $3,000 (Only if exterior paint is present)
Low-end Paint and Low-end Soil	High[j] $3,000 + $750 + $10,669		$14,419	
	Medium[k] $2,000 + $750 + $7,493		$10,243	
	Low[l] $1,000 + $750 + $4,316		$6,066	

[g] $3,000 = High-cost/Low-end interior lead paint abatement; $750 = Average-cost/High-end dust abatement; $9,600 = High-cost/High-end soil lead abatement; $750 = Average-cost/High-end dust abatement; $11,460 = High-cost hazardous soil disposal; $1,040 = High-cost soil transport; $10,000 = High-cost exterior lead paint abatement.

[h] $2,000 = Medium-cost/Low-end interior lead paint abatement; $750 = Average-cost/High-end dust abatement; $7,248 = Medium-cost/High-end soil lead abatement; $750 = Average-cost/High-end dust abatement; $7,714 = Medium-cost hazardous soil disposal; $700 = Medium-cost soil transport; $5,000 = High-cost exterior lead paint abatement.

[i] $1,000 = Low-cost/Low-end interior lead paint abatement; $750 = Average-cost/High-end dust abatement; $4,896 = Low-cost/High-end soil lead abatement; $750 = Average-cost/High-end dust abatement; $3,968 = Low-cost hazardous soil disposal; $360 = Low-cost soil transport; $3,000 = High-cost exterior lead paint abatement.

[j] $3,000 = High-cost/Low-end interior lead paint abatement; $750 = Average-cost/High-end dust abatement; $10,669 = High-cost/Low-end soil with resod every 5 years and High-end dust abatement at first resodding (see Exhibit 4-5).

[k] $2,000 = Medium-cost/Low-end interior lead paint abatement; $750 = Average-cost/High-end dust abatement; $7,493 = Medium-cost/Low-end soil with resod every 5 years and High-end dust abatement at first resodding (see Exhibit 4-5).

[l] $1,000 = Low-cost/Low-end interior lead paint abatement; $750 = Average-cost/High-end dust abatement; $4,316 = Low-cost/Low-end soil with resod every 5 years and High-end dust abatement at first resodding (see Exhibit 4-5).

4.3 SAMPLE COST CALCULATION

A sample calculation is presented below for the total cost of each abatement scenario being analyzed. These equations build on those developed in Chapter 3 Section 1.4.

The optimum net benefit model developed for Section 403 calculates total benefits and costs for a given set of assumptions regarding anticipated lead abatement choices for a 50 year time period.[6] Arriving at a present value estimate of costs or benefits for a 50 year time frame requires the application of a multiplier to the base year's cost and benefits.

$$C = \sum_{y=1}^{n} u(N_y b_{1994})F \qquad \text{Equation 4.11}$$

where:

C	=	*present value of total cost for 50 year period*
u	=	*unit cost of selected abatement for sample point y*
n	=	*number of sample points*
N_y	=	*number of homes (sample weight) for sample point y*
b_{1994}	=	*birth rate for base year (0.03994)*
F	=	*multiplying factor used to inflate cost to 50 years.*

If, in Equation 4-11, F were equal to 1 then C would equal the total cost for the base year. F is a function of birth rate, housing removal and growth rate, and discount rate. Because homes that contain lead paint are removed and replaced with homes that do not, the lead paint homes and non-lead paint homes have different growth rates and thus different inflation factors.

The multipliers used here are just the multipliers for the first year, first births derived in Chapter 3 discounted to 1994 using a seven percent rate. For lead-paint-based homes this value is 8.79; the derivation is shown in Exhibit 4-7. For lead-paint-free homes the multiplier is larger (12.48) because the population grows each year. (See Exhibit 4-8 for the calculation.)

Note that Equation 4.11 is also used to calculate the costs of lead testing. In this case, the unit cost u is the cost of testing and depends on the number of media tested. For example, if interior paint and dust are both tested, then the unit testing cost is $460. If all three media (interior paint, dust and soil) are tested, the unit cost is $598. Exterior paint testing is done only when high-end soil abatement is chosen and adds another $115 to the total unit testing costs.

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6 Fifty years was chosen as the modelling period because the net present value of the benefits accruing to children born in the fiftieth year are less than one percent of the dollar value in year fifty using a seven percent discount rate. Note benefits do not begin to accrue until age 18.

EXHIBIT 4-7
Calculation of Lead Paint House Cost Multiplier

Year (i)	Annual Components of Abatement Decisions Made	(Interest Rate)[i]	Annual Components of Abatement Cost Multiplier
1994(0)	1.0000	1.0000	1.0000
1995(1)	0.9385	1.0700	0.8771
1996(2)	0.8835	1.1449	0.7717
1997(3)	0.8298	1.2250	0.6774
1998(4)	0.7797	1.3108	0.5948
1999(5)	0.7349	1.4026	0.5240
2000(6)	0.6910	1.5007	0.4604
2001(7)	0.6629	1.6058	0.4128
2002(8)	0.6341	1.7182	0.3691
2003(9)	0.6066	1.8385	0.3300
2004(10)	0.5804	1.9672	0.2951
2005(11)	0.5554	2.1049	0.2639
2006(12)	0.5330	2.2522	0.2367
2007(13)	0.5101	2.4098	0.2117
2008(14)	0.4882	2.5785	0.1893
2009(15)	0.4673	2.7590	0.1694
2010(16)	0.4486	2.9522	0.1519
2011(17)	0.4294	3.1588	0.1359
2012(18)	0.4111	3.3799	0.1216
2013(19)	0.3936	3.6165	0.1088
2014(20)	0.3768	3.8697	0.0974
2015(21)	0.3609	4.1406	0.0872
2016(22)	0.3456	4.4304	0.0780
2017(23)	0.3310	4.7405	0.0698
2018(24)	0.3171	5.0724	0.0625
2019(25)	0.3038	5.4274	0.0560
2020(26)	0.2910	5.8074	0.0501
2021(27)	0.2788	6.2139	0.0449
2022(28)	0.2664	6.6488	0.0401
2023(29)	0.2553	7.1143	0.0359
2024(30)	0.2440	7.6123	0.0321
2025(31)	0.2340	8.1451	0.0287
2026(32)	0.2236	8.7153	0.0257
2027(33)	0.2145	9.3253	0.0230
2028(34)	0.2051	9.9781	0.0206
2029(35)	0.1967	10.6766	0.0184
2030(36)	0.1887	11.4239	0.0165
2031(37)	0.1816	12.2236	0.0149
2032(38)	0.1748	13.0793	0.0134
2033(39)	0.1682	13.9948	0.0120
2034(40)	0.1619	14.9745	0.0108
2035(41)	0.1558	16.0227	0.0097
2036(42)	0.1499	17.1443	0.0087
2037(43)	0.1443	18.3444	0.0079
2038(44)	0.1388	19.6285	0.0071
2039(45)	0.1336	21.0025	0.0064
2040(46)	0.1286	22.4726	0.0057
2041(47)	0.1237	24.0457	0.0051
2042(48)	0.1191	25.7289	0.0046
2043(49)	0.1146	27.5299	0.0042
		Abatement Cost Lead Homes Multiplier	8.7988

EXHIBIT 4.8
Calculation of Non-Lead Paint Homes Multiplier

i	Year	Births	(Interest Rate)[i]	Discounted Births
0	1994	1,885	1.00	1885.40
1	1995	1,832	1.07	1712.04
2	1996	1,782	1.14	1556.64
3	1997	1,736	1.23	1417.12
4	1998	1,693	1.31	1291.64
5	1999	1,653	1.40	1178.61
6	2000	1,616	1.50	1076.64
7	2001	1,599	1.61	995.93
8	2002	1,584	1.72	921.73
9	2003	1,569	1.84	853.47
10	2004	1,555	1.97	790.63
11	2005	1,542	2.10	732.75
12	2006	1,530	2.25	679.40
13	2007	1,519	2.41	630.20
14	2008	1,508	2.58	584.81
15	2009	1,498	2.76	542.90
16	2010	1,488	2.95	504.19
17	2011	1,483	3.16	469.45
18	2012	1,478	3.38	437.24
19	2013	1,473	3.62	407.36
20	2014	1,469	3.87	379.63
21	2015	1,465	4.14	353.89
22	2016	1,462	4.43	329.98
23	2017	1,459	4.74	307.76
24	2018	1,456	5.07	287.10
25	2019	1,454	5.43	267.90
26	2020	1,452	5.81	250.03
27	2021	1,440	6.21	231.74
28	2022	1,429	6.65	214.89
29	2023	1,418	7.11	199.34
30	2024	1,408	7.61	184.99
31	2025	1,399	8.15	171.75
32	2026	1,390	8.72	159.51
33	2027	1,382	9.33	148.20
34	2028	1,374	9.98	137.74
35	2029	1,367	10.68	128.05
36	2030	1,361	11.42	119.09
37	2031	1,357	12.22	111.02
38	2032	1,354	13.08	103.51
39	2033	1,351	13.99	96.53
40	2034	1,348	14.97	90.03
41	2035	1,346	16.02	83.99
42	2036	1,343	17.14	78.36
43	2037	1,341	18.34	73.12
44	2038	1,340	19.63	68.25
45	2039	1,338	21.00	63.71
46	2040	1,337	22.47	59.47
47	2041	1,331	24.05	55.37
48	2042	1,327	25.73	51.57
49	2043	1,322	27.53	48.03
			Total Discounted Births	23522.69
			Multiplier (Total Discounted Births/First Year Births)	12.48

4.4 RESULTS

A typical regulatory impact analysis will evaluate the costs of various regulatory alternatives. The objective of this Section 403 analysis is to choose alternative hazard levels for lead in paint, soil and dust. As a method of investigating the impacts of various levels of lead on abatement, the net benefits are used as a tool to identify possible regulatory hazard levels. The consequence of using net benefits as the identifying criterion is that the costs presented in this section are intimately tied to the benefits analysis discussed in Chapter 5 and even more so to the benefit-cost results examined in Chapter 6. A brief discussion of the approaches used in the model is contained in Chapter 3, and a thorough discussion in Chapter 6.

4.4.1 Total Abatement Costs

To serve as an appropriate guide for public policymaking, the cost estimates used in this analysis should be consistent with the concept of social costs. Because the data sources generally provided estimates of private costs, it is reasonable to determine whether there are any divergences between these estimated costs and social costs. This evaluation must be conducted for each of the economic resources used in response to the promulgation of hazard levels under Section 403. For the current discussion, these resources are classified generally as labor and capital and discussed in turn below.[7]

The most common source of divergence between private and social costs of labor is associated with unemployment. When unemployment exists, the costs of employing additional labor may be lower than the prevailing wage implies. Consequently, if the regulation being considered here causes unemployed labor to be used, the price of labor is not accurately represented by the prevailing wage. Gramlich proposes conditions to be met if unemployed labor is to be valued at less than market rates in benefit-cost analyses (Gramlich, 1981). Given the fifty-year timeframe of this analysis, it is unclear whether two of these conditions can be met, except intermittently, in the case of the hazard levels to be set under Section 403. The first is that the reduction in unemployment must be sustained, meaning that reduced unemployment today does not lead to inflation that generates more unemployment later. The second condition is that the abatements and other actions induced by the promulgation hazard levels do indeed lead to unemployment reductions that existing policies would not have addressed. Abatements induced by this regulation will create additional demand for labor but it is unclear how much unemployed labor will be provided to meet this additional demand. In part, making this determination is difficult since the size and composition of the pool of unemployed labor will fluctuate as the economy changes over the next 50 years.

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7 It is hard to summarize here the possible divergences between the social and private costs of a third class of resources - the environment - since that in many ways is the focus of this analysis, as the discussion of market failures in Chapter 3 indicated. Instead, any divergences between social and private costs of using the environment are discussed as they arise throughout this report. One example of such a divergence comes in the form of the positive externality to future residents from the abatement of a given home, which is modelled in the benefit estimation.

Without an indication that the social costs of labor will be less than the private costs during the time period of this analysis, it was assumed that private labor costs adequately reflect social costs. This position is bolstered by the likelihood that the estimates of private costs used in this analysis may be too low during periods of high demand for the type of labor used in abatement. In short, there are downward and upward tendencies to the labor estimates used here from the social costs of labor they are meant to represent. These tendencies imply that any point estimate of labor costs may have a great deal of variance associated with it. However, the direction of any net biases are unknown.

With regard to capital, one of the most common forms of divergence between social and private costs hinges on whether investment is displaced by the lead abatements and other actions induced by this rule. The opportunity cost of displaced investment is the present value of the consumption stream that could be generated by that investment. This concept is also known as the shadow price of capital. At one extreme, if investment is completely displaced, capital costs should be multiplied by the shadow price of capital, which is estimated to be approximately 2.5, in order to express the capital costs in terms of consumption, and then discounted back to the present using the social rate of time preference (Scheraga, 1989). At the other extreme, if no investment is to be displaced, abatement costs must be funded entirely from current consumption (implying a shadow price of capital equal to one). An assumption of no displacement of investment was applied in the main analysis. An alternative approach which allows for displacing investment over varying timeframes is considered in sensitivity analyses in Chapter 7. These analyses are based upon a two-stage discounting procedure.

The total cost of any of the decision rules is the sum of the testing and abatement costs. These, in turn, are a function of the number of homes undergoing testing and abatement and the type of testing or abatement being done. Exhibit 4-9 shows the costs by abatement type for each of the five decision rules used in this analysis. (See Chapter 3 Section 3.4 for a discussion of the decision rules.) Exhibit 4-10 shows the number of homes abated by type of abatement for each rule. The results discussed here were calculated using the medium value of the abatement costs discounted at seven percent as shown in Exhibits 4-5 and 4-6. Results for high and low abatement costs as well as costs calculated using the two-stage discounting procedure will be discussed as part of the sensitivity analyses in Chapter 7.

The total testing costs for each decision rule are shown in Exhibit 4-9. For the four decision rules that did not have an explicit dust condition or did not permit non-recurrent dust abatement as an option, only interior paint (in pre-1980 homes) and soil were tested. The resulting total testing costs were $14,982 million. For the remainder of the decision rules, all three media were tested. In the voluntary optimum case, no exterior paint testing was required because the high-end soil abatement was never chosen. The total testing costs were $24,222 million. In the remaining four decision rules, exterior paint testing costs were added for a total of $24,346 million. The testing costs and abatement costs are summed to yield the total costs discussed below.

EXHIBIT 4-9

Total Costs for Five Alternative Decision Rules

Decision Rules[a]		Soil (ppm)	Dust (ppm)	Paint (XRF, mg/cm²)	Nonintact Paint Abatement Recommended	Abatement Costs ($ million)	Testing Costs ($ million)	Total Costs ($ million)	Costs by Type of Abatement Chosen[g] ($ million)									
									HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NRD
1. Voluntary Optimum[b]		-	-	-	No	13,896	24,222	38,118		26		1,992						11,878
2. Paint Condition Only[c]		-	-	-	Yes	24,668	14,982	39,650	20,134	3,517					943		74	
3. Single Medium Plus Condition[d]	3a.	2,300	-	-	Yes	28,344	14,982	43,326	20,134	3,442		3,475			943		350	
	3b.	-	1,200	-	Yes	29,646	24,346	53,992	20,260	3,462	272	1,420	978		943	87	74	2,150
	3c.	-	-	20	Yes	25,013	14,982	39,995	20,429	3,567					943		74	
4. 2-Media Plus Condition[e]	4a.	2,300	1,200	-	Yes	31,903	24,346	56,249	20,260	3,387	272	3,475	978		943	87	350	2,150
	4b.	2,300	-	20	Yes	28,689	14,982	43,671	20,429	3,493		3,475			943		350	
	4c.	-	1,200	20	Yes	29,991	24,346	54,337	20,555	3,551	272	1,420	978		943	87	74	2,150
5. 3-Media Plus Condition[f]		2,300	1,200	20	Yes	32,248	24,346	56,594	20,555	3,438	272	3,475	978		943	87	350	2,150

[a] Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust and 20 mg/cm²

[b] Each home selects abatement (or no abatement) that has highest net benefits

[c] Abatement is recommended for homes with more than five square feet of lead -based paint in nonintact condition, regardless of XRF level or net benefits. Home owners choose the paint abatement method that generates the highest net benefits. Results are reported only for homes that exceed recommended levels.

[d] Within the full range of individual soil, dust and paint hazard levels that could be set as a threshold for action, with no constraints placed ont eh other two media, the levels specified in the table maximize the net benefits. Results are reported only for homes that exceed recommended levels.

[e] Within the full range of individual soil, dust and paint hazard level combination that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize the net benefits. Results are reported only for homes that exceed recommended levels.

[f] Within the full range of individual soil, dust and paint hazard level combination that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize the net benefits. Results are reported only for homes that exceed recommended levels.

[g] Abatement Codes: High Paint(HP); Low Paint(LP); High Soil(HS); Low Soil(LS); Recurrent Dust (RD); High Paint and High Soil(HP/HS); High Paint and Low Soil(HP/LS); Low Paint and High Soil (LP/HS); Low Paint and Low Soil (LP/LS); Nonrecurrent Dust (NRD). The abatement activities were described in Exhibits 4.1-4.6.

EXHIBIT 4-10

Distribution of Abatement Choices for Five Alternative Decision Rules

Decision Rules[a]			Soil (ppm)	Dust (ppm)	Paint (XRF, mg/cm²)	Nonintact Paint Abatement Recommended	Total Number of Abatements (Thousands)	Number of Abatements by Type Chosen[g] (Thousands)									
								HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NRD
1.	Voluntary Optimum[b]		-	-	-	No	45,165		21		577						44,567
2.	Paint Condition Only[c]		-	-	-	Yes	7,064	4,160	2,774					114		16	
3.	Single Medium Plus Condition[d]	3a.	2,300	-	-	Yes	8,070	4,160	2,716		1,006			114		74	
		3b.	-	1,200	-	Yes	15,603	4,186	2,731	74	411	276		114	18	16	7,777
		3c.	-	-	20	Yes	7,164	4,220	2,814					114		16	
4.	2-Media Plus Condition[e]	4a.	2,300	1,200	-	Yes	16,197	4,186	2,672	74	1,006	276		114	18	74	7,777
		4b.	2,300	-	20	Yes	8,169	4,220	2,755		1,006			114		74	
		4c.	-	1,200	20	Yes	15,702	4,246	2,770	74	411	276		114	18	16	7,777
5.	3-Media Plus Condition[f]		2,300	1,200	20	Yes	16,297	4,246	2,712	74	1,006	276		114	18	74	7,777

[a]Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust and 20 mg/cm²

[b]Each home selects abatement (or no abatement) that has highest net benefits

[c]Abatement is recommended for homes with more than five square feet of lead -based paint in nonintact condition, regardless of XRF level or net benefits. Home owners choose the paint abatement method that generates the highest net benefits. Results are reported only for homes that exceed recommended levels.

[d]Within the full range of individual soil, dust and paint hazard levels that could be set as a threshold for action, with no constraints placed ont eh other two media, the levels specified in the table maximize the net benefits. Results are reported only for homes that exceed recommended levels.

[e]Within the full range of individual soil, dust and paint hazard level combination that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize the net benefits. Results are reported only for homes that exceed recommended levels.

[f]Within the full range of individual soil, dust and paint hazard level combination that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize the net benefits. Results are reported only for homes that exceed recommended levels.

[g]Abatement Codes: High Paint(HP); Low Paint(LP); High Soil(HS); Low Soil(LS); Recurrent Dust (RD); High Paint and High Soil(HP/HS); High Paint and Low Soil(HP/LS); Low Paint and High Soil (LP/HS); Low Paint and Low Soil (LP/LS); Nonrecurrent Dust (NRD). The abatement activities were described in Exhibits 4.1-4.6. discussed below.

The voluntary optimum decision rule has the lowest total costs of any of the rules considered ($38,118 million) and the largest number of abatements recommended, just over 45 million. The overwhelming majority of the abatements were non-recurrent dust, the lowest unit cost abatement. Once constraining conditions are added to the decision rules, the total costs rise, not because the number of abatements increases (in fact they decrease), but because the types of abatements necessary to meet the decision rule requirements have higher unit costs.

The remaining eight decision rules all recommend nonintact paint abatement as either part or all of the abatement. One of these decision rules recommends only nonintact paint be abated; in this case, 7 million abatements are performed at a total testing and abatement cost of $40 billion. While fewer abatements are performed under this rule than under the voluntary optimum, they are paint abatements (alone or in combination with soil abatements), that have higher unit costs than non-recurrent dust abatement, the voluntary optimum preferred choice. The lower testing costs under this decision rule result from testing only paint and soil. Because dust abatement will not satisfy the constraining condition (that paint in bad condition be abated), there is no need for dust testing.

The next seven constrained decision rules each have higher costs and a larger number of abatements. The non-intact paint abatement condition, with a cost of $24.6 billion, represents the majority of the abatement cost in all the remaining rules. The single media constrained cases add to this base. A soil condition at 2,300 ppm adds about $3.7 billion to the paint condition base cost, the 1,200 ppm dust condition adds both soil and dust abatements totaling $5 billion. An intact paint XRF condition of 20 mg/cm^2 adds less than half a billion dollars to the nonintact paint abatement cost. The three two-media constrained decision rules also add costs to the paint condition base. With a decision rule of abating soil to 2,300 ppm and dust to 1,200, the additional cost is about $7 billion. Adding soil at 2,300 ppm and paint at 20 mg/cm^2 adds only $4 billion while adding dust (1,200 ppm) and paint (20 mg/cm^2) conditions adds $5.3 billion. Finally, the three media constrained case adds $7.6 billion to the paint condition base making it the most costly option considered. Chapter 6 will compare the costs incurred to the monetized benefits discussed in Chapter 5.

4.4.2 Quantity of Hazardous Waste Generated by Abatement

The amount of hazardous waste that will be generated under each decision rule, based on the Resource Conservation and Recovery Act (RCRA) disposability requirements, is an additional consideration when evaluating the hazard level choices. The applicability of the RCRA standards and the potential quantity of waste generated is described below for each medium. As was discussed in Section 4.2.2, the Agency has yet ruled on whether residential lead abatement wastes will be considered hazardous waste. It is also possible that the hazardous wastes generated will be treated, and disposed of as non-hazardous waste, in which case the hazardous waste capacity would not be an issue.

Paint

In the Housing and Urban Development abatement demonstration project, an average of 217 pounds of hazardous waste was generated per housing unit in the three cities for which data was available (US EPA, 1992a). This estimate does not include all the large solid debris which was not considered hazardous. The method of abatement used may affect the amount of hazardous waste generated, however, chemical stripping and abrasive removal, methods more likely to create hazardous waste, were not considered in our model, nor are they likely to be widely used. Because the disposal cost is a small percentage of the overall paint abatement cost no explicit consideration of hazardous waste disposal was included in the modelled abatement cost. A second consideration however, is the total quantity of waste that would be generated under each of the proposed decision rules. Exhibit 4-11 shows the total and annualized volume of hazardous waste from paint abatement. These values are compared to the total quantity of hazardous waste, 197,501,112 tons, generated in the United States in 1989 (US EPA, 1992b). As Exhibit 4-11 shows, the hazardous waste generated by lead-based paint abatement is less than a tenth of a percent of the total national annual hazardous waste generation.

Dust

Dust abatement is expected to generate a very small quantity (<20 pounds/unit) of waste that could be considered hazardous. This was assumed to be excluded from RCRA regulation under the household waste exemption criterion (Fortuna, 1987).

Soil

The hazardous waste from soil was explicitly considered in the cost of soil abatement when the soil was abated by removal. The medium cost estimate presented in this report assumed removal of 35.9 tons of soil per unit. Using this value and the number of high-end soil abatements as reported by decision rule in Exhibit 4-10, the total quantity of hazardous soil generated was calculated for each decision rule. The results are shown in Exhibit 4-11. The total annual contribution of soil abatement is less than one tenth of one percent of the total hazardous waste generated annually. Based on these results the quantity of hazardous waste generated is not a significant concern although the cost contribution of disposing of the waste could be significant.

EXHIBIT 4-11

Volume of Hazardous Waste Generated by Media for Five Alternative Decision Rules

Decision Rules[a]			Soil (ppm)	Dust (ppm)	Paint (XRF, mg/cm²)	Nonintact Paint Abatement Recommended	Total Volume of Hazardous Waste Generated Over Fifty Years (Thousand Tons)	Volume of Hazardous Waste Generated Over Fifty Years by Media and Decision Rule[g] (Thousand Tons)		Volume of Hazardous Waste Generated Annually by Media and Decision Rule (Thousand Tons)		Lead Abatement Hazardous Waste as Percent of Total Hazardous Waste Generated Annually
								Paint	Soil	Paint	Soil	
1.	Voluntary Optimum[b]		-	-	-	No	2	2	0	.04	0	<.0001%
2.	Paint Condition Only[c]		-	-	-	Yes	696	696	0	14	0	.007%
3.	Single Medium Plus Condition[d]	3a.	2,300	-	-	Yes	696	696	0	14	0	.007%
		3b.	-	1,200	-	Yes	3,998	696	3,303	14	66	.04%
		3c.	-	-	20	Yes	705	705	0	14	0	.007%
4.	2-Media Plus Condition[e]	4a.	2,300	1,200	-	Yes	3,998	696	3,303	14	66	.04%
		4b	2,300	-	20	Yes	705	705	0	14	0	.007%
		4c.	-	1,200	20	Yes	4,008	705	3,303	14	66	.04%
5.	3-Media Plus Condition[f]		2,300	1,200	20	Yes	4,008	705	3,303	14	66	.04%

[a]Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust and 20 mg/cm²

[b]Each home selects abatement (or no abatement) that has highest net benefits

[c]Abatement is recommended for homes with more than five square feet of lead -based paint in nonintact condition, regardless of XRF level or net benefits. Home owners choose the paint abatement method that generates the highest net benefits. Results are reported only for homes that exceed recommended levels.

[d]Within the full range of individual soil, dust and paint hazard levels that could be set as a threshold for action, with no constraints placed ont eh other two media, the levels specified in the table maximize the net benefits. Results are reported only for homes that exceed recommended levels

[e]Within the full range of individual soil, dust and paint hazard level combination that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize the net benefits. Results are reported only for homes that exceed recommended levels.

[f]Within the full range of individual soil, dust and paint hazard level combination that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize the net benefits. Results are reported only for homes that exceed recommended levels.

4.5 REFERENCES

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5. BENEFITS

5.1 GENERAL ASSUMPTIONS

Chapter 3 provided a description of the methodology used to produce the "baseline" hazard assessment of children's exposure to lead from paint, soil and dust in US private housing stock. A basic premise of the baseline hazard assessment is that in the absence of establishing Section 403 hazard levels to induce property owners to perform abatements, children born each year over the next several decades will experience exposure to lead from paint, soil and dust in patterns that are, for the most part, similar to current exposure patterns. As a result, they will also incur the health damages associated with those patterns of exposure.

As discussed in Chapter 3, the baseline hazard assessment does account for some improvement in the profile of childhood lead exposure over the 50 year modeling time frame to reflect the expected attrition of older housing stock where lead paint can still be found, with a concurrent increase in the number and proportion of newer homes without lead paint. However, it was assumed in the baseline hazard assessment that no property owners would undertake specific abatements to reduce or eliminate lead currently present in paint, soil or dust.[1]

To estimate the benefits expected to result from abatements assumed to be induced by the Section 403 hazard levels, a series of "what-if" analyses were performed. Three sets of assumptions were necessary to conduct these "what if" analyses. These were:

1) A set of assumptions defining decision rules incorporating the Section 403 hazard levels;

2) A set of assumptions regarding the nature of the responses by property owners to those hazard levels in terms of the specific abatement actions to be undertaken; and

3) A set of assumptions regarding the change in children's exposure conditions as a result of undertaking those abatements.

These three sets of assumptions are discussed further in the following sections.

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[1] As noted in Chapter 3, this "no abatements" assumption incorporated in the baseline analysis is recognized as being extreme, since there are abatements of paint, soil and dust currently being performed in the absence of these regulations.

5.1.1 Decision Rule Assumptions

The first set of assumptions, regarding the selection of hazard levels to be evaluated, has been discussed in Section 3.4, and is dealt with in detail in Chapter 6. The specific decision rules addressed are summarized in Exhibit 5-1.

As discussed in Chapter 3.4 and Chapter 6, the specific paint, soil and dust values identified as the hazard levels in these decision rules were, with the exception of the 500/400/- option, arrived at through the consideration of the estimated net benefits produced That is, among all of the three media combinations, two media combinations, and single media options of paint, soil and dust hazard levels considered, the decision rules with the hazard levels presented in Exhibit 5-1 were the ones that maximized net benefits, given those other assumptions.

The Voluntary Optimum decision rule is a special case in which no specific hazard levels are set for paint, soil or dust; rather it is assumed that individual property owners will choose to perform abatements that provide maximum positive net benefits, or will perform no abatement if none of the options produces positive net benefits.

The hazard levels in the 500/400/- decision rule that is included in this analysis were not based on net benefits considerations. Rather, it was based on an individual risk perspective, using the probability of exceeding certain critical blood lead levels as the "trigger" for inducing abatements. Suppose for example that a household facing an abatement decision (i.e., expecting a child in the ensuing year) has lead paint in good condition at an XRF of 19, soil lead at 2,200 ppm, and dust lead at 1,100 ppm. Since these values are just below those that would induce abatement in any of these media according to the net benefits analysis, it would be assumed under those decision rules that no abatement would be done. However, the blood lead geometric mean predicted by the IEUBK for a population of children exposed to these levels is 15.3 μg/dl. At this level, and assuming a GSD of 1.6, the probability of exceeding several frequently targeted blood lead levels of concern are:

81.7% chance of exceeding 10 μg/dl
51.7% chance of exceeding 15 μg/dl
28.4% chance of exceeding 20 μg/dl
14.8% chance of exceeding 25 μg/dl

from model?

Because one of the primary objectives of setting hazard levels is to reduce or eliminate children's risk of adverse health effects due to lead exposure from these sources, and because CDC now considers blood lead levels down to 10 μg/dl to be of concern from a health effects standpoint, it was felt necessary to also include consideration of a decision rule in the benefits analysis that was aimed specifically at minimizing the incidence of these high blood lead levels, notwithstanding the net benefits of that rule.

Exhibit 5-1. Summary of Decision Rules and Hazard Levels		
Decision Rule	**Description**	**Basis**
Voluntary Optimum	No specific hazard levels are set; individual property owners undertake those abatements (if any) producing the maximum positive net benefits.	This decision rule produces the maximum net benefits of all rules considered.
Paint Condition Only	Interior lead paint in bad condition always induces abatement, regardless of lead level; however, no hazard levels set for paint in good condition, dust lead, or soil lead.	Since all other decision rules (except the Voluntary Optimum) include a hazard level for paint based on bad condition, this decision rule provides a means of discerning the portion of the benefits from those other rules contributed by this component.
2300/1200/20	Interior lead paint in bad condition always induces abatement, regardless of lead level; and hazard levels set at: Soil = 2,300 ppm Dust = 1,200 ppm XRF = 20 for paint in good condition	This decision rule was found to have the highest net benefits among all combinations considered that included specific hazard levels for all three media, with paint condition included.
2300/-/20	Interior lead paint in bad condition always induces abatement, regardless of lead level; and hazard levels set at: Soil = 2,300 ppm Dust = no level set XRF = 20 for paint in good condition	This decision rule was found to have the highest net benefits among all combinations considered that included specific hazard levels for soil and good condition paint, with paint condition included.
-/1200/20	Interior lead paint in bad condition always induces abatement, regardless of lead level; and hazard levels set at: Soil = no level set Dust = 1200 ppm XRF = 20 for paint in good condition	This decision rule was found to have the highest net benefits among all combinations considered that included specific hazard levels for dust and good condition paint, with paint condition included.
2300/1200/-	Interior lead paint in bad condition always induces abatement, regardless of lead level; and hazard levels set at: Soil = 2,300 ppm Dust = 1,200 ppm XRF = no level set	This decision rule was found to have the highest net benefits among all combinations considered that included specific hazard levels for soil and dust, with paint condition included.
2300/-/-	Interior lead paint in bad condition always induces abatement, regardless of lead level; and hazard levels set at: Soil = 2,300 ppm Dust = no level set XRF = no level set	This decision rule was found to have the highest net benefits among all combinations considered that included specific hazard levels for soil only, with paint condition included.
-/1200/-	Interior lead paint in bad condition always induces abatement, regardless of lead level; and hazard levels set at: Soil = no level set Dust = 1,200 ppm XRF = no level set	This decision rule was found to have the highest net benefits among all combinations considered that included specific hazard levels for dust only, with paint condition included.
-/-/20	Interior lead paint in bad condition always induces abatement, regardless of lead level; and hazard levels set at: Soil = no level set Dust = no level set XRF = 20 for paint in good condition	This decision rule was found to have the highest net benefits among all combinations considered that included specific hazard levels for good condition paint, with paint condition included.
500/400/-	Interior lead paint in bad condition always induces abatement, regardless of lead level; and hazard levels set at: Soil = 500 ppm Dust = 400 ppm XRF = no level set	This decision rule was designed to minimize individual risk of exceeding specific target blood lead levels (see discussion in text).

Shown in Exhibit 5-2, below, are back-calculations of the value for the geometric mean that will keep 90%, 95%, or 99% of the population below the specific blood lead target of 10, 15, 20 and 25 μg/dl (assuming in all cases a GSD of 1.6). So, for example, for an individual child to have ≥ 90% chance that his or her blood lead will not exceed 10 μg/dl (or, conversely, <10% chance that it will exceed 10 μg/dl), that child's exposure conditions should lead to an estimated geometric mean blood lead value of 5.48 μg/dl or less. Similarly, to have a 95% chance of having a blood lead below 15 μg/dl, the predicted geometric mean for those exposure conditions should be less than 6.92 μg/dl.

Exhibit 5-2. Geometric Means (in μg/dl) to Achieve Indicated Blood Lead Targets

	GM to keep 90% of population below indicated PbB target	GM to keep 95% of population below indicated PbB target	GM to keep 99% of population below indicated PbB target
	(Assumes a GSD of 1.6)		
PbB target: 10 μg/dl	**5.48**	4.62	3.35
15 μg/dl	8.21	**6.92**	5.03
20 μg/dl	10.95	9.23	**6.70**
25 μg/dl	13.69	11.54	8.38

Given the most recent guidance provided by CDC for blood lead levels of concern, goals were assumed for a set of lead hazard levels that will limit individual risk of exceeding key target blood lead levels to:

Approximately 90% chance of blood lead less than 10 μg/dl, and
Approximately 95% chance of blood lead less than 15 μg/dl, and
Approximately 99% chance of blood lead less that 20 μg/dl.

Considering the geometric means in Exhibit 5-2, these goals would be met by the blood lead geometric means in the bolded cells. For the purpose of this analysis, a value in the middle of this range of 6.5 μg/dl has been selected as the target geometric mean blood lead to approximate the above stated risk targets.

Based on the IEUBK model runs, a series of soil and dust combinations were identified that produce a geometric mean of approximately 6.5 μg/dl. These combinations included some having very high dust levels in combination with low soil levels (e.g., dust = 800 ppm; soil = 11 ppm), and some having very high soil levels in combination with low dust levels (soil = 958 ppm; dust = 25 ppm). The specific hazard levels selected for this decision rule were soil = 500 ppm and dust = 400 ppm, which avoided the extremes of combinations producing the same risk levels. It should be noted that this decision rule also includes the assumption that lead paint in bad condition will always induce abatement. No hazard level was included for lead paint in good condition, since it was found that adding such a hazard level would not substantially affect the predicted blood lead levels (see Section 5.3).

5.1.2 Abatement Choice Assumptions

The second set of assumptions are also discussed in part in Chapter 3.4 as well as in Chapter 4. Briefly, it has been assumed that property owners facing an abatement decision will choose an abatement type that will reduce their paint, soil and/or dust levels to be in conformance with the Section 403 hazard levels, and will choose from among alternatives able to accomplish this goal, the abatement alternative that maximizes the net benefits.

As described in Chapter 4, there are 10 specific abatement choices considered in this analysis. These include two paint abatements (high-end and low-end paint abatements); two soil abatements (high-end and low-end soil abatements); four combined paint and soil abatements (high-end paint with high-end soil; high-end paint with low-end soil; low-end paint with high-end soil; and low-end paint with low-end soil); and two dust abatements (recurrent and non-recurrent).

5.1.3 Post-Abatement Exposure Condition Assumptions

The third set of assumptions, those regarding the change in exposure conditions as a result of undertaking a specific type of abatement, were discussed in part in Chapter 4 with respect to the effectiveness of the various types of abatement considered.

The assumed post-abatement conditions for each alternative are summarized in Exhibit 5-3. Post-abatement conditions for the combined paint and soil abatements simply reflect the combination of post abatement conditions for each separately. The "calculated" dust values referred to in Exhibit 5-3 are explained below.

It is generally recognized that the lead present in dust in homes originates primarily from lead in paint at that home and in the soil in proximity to that home. As discussed in Chapter 4, we have assumed that all paint and soil abatements will also include dust abatement. Therefore, whenever homes perform abatements of paint or soil, there is an expected concomitant reduction in the level of lead in the dust in that home. It was therefore necessary to incorporate an algorithm in the benefits analysis to estimate what those post-abatement dust levels would be.

Exhibit 5-3. Summary of Post-Abatement Conditions for Various Abatement Alternatives

Abatement Alternative	Assumed Post-Abatement Conditions
High End Paint Abatement	• Paint: No interior lead paint remains. • Soil: No change in soil lead concentration. • Dust: Uses lower of HUD value or calculated value.
Low End Paint Abatement	• Paint: No lead paint on windows; intact lead paint remains on other surfaces. • Soil: No change in soil lead concentration. • Dust: Uses lower of HUD value or calculated value.
High End Soil Abatement	• Paint: No change in interior lead paint levels of condition. • Soil : Lead concentration reduced to 100 ppm. • Dust: Uses lower of HUD value or calculated value.
Low End Soil Abatement	• Paint: No change in interior lead paint levels of condition. • Soil : Lead concentration reduced to 500 ppm • Dust: Uses lower of HUD value or calculated value.
Recurrent Dust Abatement	• Paint: No change in interior lead paint levels of condition. • Soil: No change in soil lead concentration. • Dust : Lead concentration reduced to 100 ppm.
Non-recurrent dust	• Paint: No change in interior lead paint levels of condition. • Soil: No change in soil lead concentration. • Dust : Reduced to calculated value.

The algorithms used were based on relationships provided in the December 1991 draft Guidance Manual for the IEUBK model. The basic relationships provided there were:

$$PbD = [366 + (83.5 \bullet (PbP - 1.0))] + [0.9 \bullet PbS] \qquad \text{(Equation 5-1)}$$

where *PbD* is the dust lead concentration in ppm; *PbP* is the maximum interior paint XRF measurement; and *PbS* is the soil lead concentration in ppm.

In the Guidance Manual, this relationship is modified slightly for low XRF values. If the XRF value is greater than 0 but less than or equal to 1, the equation becomes:

$$PbD = 252 + [0.9 \bullet PbS] \qquad \text{(Equation 5-2)}$$

If there is no lead paint (i.e., XRF = 0), the relationship is:

$$PbD = [0.9 \bullet PbS] \qquad \text{(Equation 5-3)}$$

Two exceptions exist to using these calculated post-abatement dust levels. The first is in the case of recurrent dust abatement. Because it is assumed that the recurrent dust abatement option is undertaken for the express purpose of minimizing dust lead levels without performing any paint or soil abatement, it was necessary to make an assumption as to the effectiveness of this option. It is assumed in this case that the recurrent dust abatement will yield an effective dust level is 100 ppm.

The second exception to using these calculated dust values for post-abatement conditions is when the original HUD dust value is lower than the post-abatement value calculated from the above algorithms. In these cases, the lower HUD value was used to avoid having an outcome where the post-abatement dust level exceeded the baseline dust level.

As noted in Chapter 3, the risk modeling (and therefore the benefits modeling as well) cannot at present differentiate between the health damages to children whose soil lead exposure is predominately bare soil from the damages to children whose exposure is mainly from covered soils. As discussed in Chapter 3, no information is available to differentiate between bare and covered soils in the baseline risk assessment. It is assumed, however, that the post-abatement soils are all grass-covered. Because the intake of lead from exposure to bare soils is expected to be greater than from exposure to covered soils (all other factors being equal, such as lead concentration and soil type), the benefits of soil abatement may be underestimated for those cases where the starting condition is bare soil, and overestimated where the starting condition is covered soils. As noted in Chapter 3, it is assumed that these factors largely compensate for one another in the aggregate estimate of the baseline damages and the benefits of soil abatement. It is not known, however, how reasonable this assumption is, since neither the distribution of the incidence of bare vs. covered soils in residential settings, nor the relationships between soil condition and blood lead levels are known. In Chapter 7, this issue is discussed further in the context of its potential effects on benefit-cost comparisons and identifying hazard levels that maximize net benefits.

5.2 BENEFITS MODELING PROCESS

The modeling process for estimating the benefits resulting from various combinations of decision rules and abatement choices parallels that described in detail in Chapter 3 for the baseline hazard assessment. Consider, for example, the first year of the 50 year modeling time frame. In the baseline hazard assessment, the first year's cohort of children are assumed to experience exposure to lead in paint, soil and dust as estimated from the HUD data and other assumptions described previously. In essence, the abatement decision being made in the baseline assessment in anticipation of these new children arriving is "no abatement." Alternative analyses were therefore performed to calculate the effect of undertaking each of the 10 viable abatement options at each of these homes. To do this, the baseline levels of lead in paint, soil, and/or dust were replaced with the assumed post-abatement conditions, as summarized in Exhibit 5-3.

Using these post-abatement paint, soil and dust lead levels, the modeling process is then identical to that used in the baseline hazard assessment. That is, these reduced exposure levels are used in the IEUBK model, maintaining all other IEUBK assumptions as before, to arrive at a new, lower estimate of the geometric mean for subpopulations of children in each housing category. These lower geometric means, again with the assumption of a geometric standard deviation of 1.6, are used to define the blood lead distribution for these children. Using the first year cohort of children, an estimate is made of the incidence of IQ points lost, cases of IQ < 70, incidence of blood leads > 25 μg/dl, and neonatal mortality. As discussed in Chapter 3, the estimated incidence of these effects for the remaining 49 years of the modeling time frame are obtained through the use of multipliers that reflect anticipated changes in birth rates and housing stock levels over the full modeling period.

As indicated before, the benefits for undertaking a particular set of abatements in response to a given decision rule is calculated as the difference between the baseline estimate of the incidence of these effects and the estimates obtained with the assumed abatements having been performed.

It is important to note that in modeling the benefits and costs of hazard level / abatement choice combinations, we assume always that when abatements are done, they are only done in conjunction with the anticipated arrival of a new child in the ensuing year. That is, abatements are not assumed to be done on homes just because they exceed the lead paint, soil and/or dust hazard levels. The imminent arrival of a new child is assumed to be the trigger for making abatement decisions, using the Section 403 hazard levels to guide the specific abatement choice. It is also important to note that the modeling of benefits has assumed that property owners facing an abatement decision will always choose to perform some abatement if they exceed specified hazard levels (i.e., there are no non-compliers).

5.3 ESTIMATED BENEFITS AS AVOIDED INCIDENCE OF ADVERSE EFFECTS

This section presents the estimated benefits of the various Section 403 decision rules in terms of impacts on population blood lead levels and avoided incidence of the specific adverse health effects addressed, namely IQ point loss, IQ < 70, blood lead > 25 μg/dl, and neonatal mortality. For the purpose of comparing the different decision rules, the blood lead distribution changes and avoided incidence estimates presented in this section reflect only the first model year. Since the multipliers used to determine the avoided incidence of these effects across the entire modeling period are the same for the baseline and all post-abatement scenarios, the relative order of benefits is the same in the first year as it would be over the full modeling time frame.

Since most of the benefits computed are directly associated with the changes that abatements have on the population blood lead distribution, it is useful to first compare how different decision rules affect the blood lead distributions. Exhibit 5-4 provides a summary comparison of the blood lead distributions for the baseline with those resulting from the various decision rules for the first model year cohort. One general observation about the blood lead changes (which applies to most other measures of benefits as well) is that the inclusion in a decision rule of the XRF = 20 hazard level for paint in good condition has little or no effect on the estimated benefits relative to a similar decision rule without the XRF constraint.

The largest downward shifts in the blood lead distributions were observed in the two "special case" decision rules, i.e., the Voluntary Optimum and the 500/400/- rule. The latter of these had the greatest impact, with a predicted downward shift in the geometric mean from a baseline value of 4.06 μg/dl to 2.45 μg/dl. The Voluntary Optimum was close behind this with a downward shift in the geometric mean to a value of 2.52 μg/dl. However, the 500/400/- decision rule has a much larger impact in terms of reducing the size of the upper tail of the distribution, showing for example only about 2.4% of the population expected to be above 15 μg/dl, versus 9.0% above this level for the Voluntary Optimum.

Among the several three-media, two-media and single-media decision rules based on maximum net benefits, the largest effects are seen for the options that include both soil at 2,300 ppm and dust at 1,200 ppm. Again, adding an XRF = 20 hazard level for paint in good condition has no significant effect on the predicted blood lead distribution. The decision rule options with dust of 1,200 without a soil hazard level results in a greater downward shift in the blood lead distribution than the options with a soil hazard level of 2,300 without a dust hazard level. The least effective decision rules are those that place a hazard level only on paint in good condition, with no constraints on either soil or dust. It should also be noted that while the downward shift in the geometric mean is greater for the Voluntary Optimum than for these rules based on maximum net benefits, all of these latter rules have lower predicted GSDs, and consequently result in slightly lower portions of the population in the upper tail than predicted for the Voluntary Optimum. This is primarily a result of the underlying assumption that, in the rules based net-benefits, all homes with lead paint in bad condition will undergo abatement when a child is expected, an assumption that is not included in the voluntary optimum.

Exhibit 5-4. Summary of Post-Abatement Blood Lead Distribution Characteristics by Decision Rule

Decision Rule	Mean	Geometric Mean	Geometric Standard Deviation	Median	90th Percentile	95th Percentile	% > 10 µg/dl	% > 15 µg/dl	% > 20 µg/dl	% > 25 µg/dl
Baseline	6.08	4.06	2.45	3.91	13.30	18.83	15.96%	8.01%	4.35%	2.46%
Voluntary Optimum	4.11	2.52	2.70	2.45	9.47	13.39	9.05%	3.81%	1.72%	0.82%
Paint Condition Only	5.75	3.82	2.47	3.72	12.55	17.73	14.63%	7.12%	3.77%	2.08%
Soil = 2300 Dust = 1200 XRF = 20	4.64	3.30	2.35	3.36	9.67	12.78	9.24%	3.13%	1.16%	0.46%
Soil = 2300 Dust = 1200 No XRF value	4.64	3.30	2.35	3.36	9.67	12.78	9.24%	3.13%	1.16%	0.46%
Soil = 2300 No Dust Value XRF = 20	5.58	3.78	2.43	3.71	11.99	16.65	13.87%	6.33%	3.16%	1.67%
No soil value Dust = 1200 XRF = 20	4.73	3.32	2.37	3.36	9.81	13.19	9.57%	3.54%	1.50%	0.69%
Soil = 2300 No Dust value No XRF value	5.58	3.78	2.43	3.71	11.99	16.65	13.88%	6.33%	3.16%	1.67%
No soil value Dust = 1200 No XRF value	4.73	3.32	2.39	3.36	9.81	13.19	9.57%	3.54%	1.50%	0.69%
No soil value No dust value XRF = 20	5.75	3.82	2.47	3.72	12.55	17.73	14.62%	7.12%	3.77%	2.08%
Soil = 500 Dust = 400 No XRF value	3.24	2.45	2.20	2.56	6.43	8.12	2.39%	0.39%	0.08%	0.02%

Note: All decision rules except the Voluntary Optimum also include paint in bad condition as a hazard level regardless of XRF value; XRF values shown in the above decision rules refer to good condition paint.

Exhibit 5-5 summarizes the effect of these rules in terms of avoided IQ point loss and avoided incidence of IQ < 70 for the first year cohort. In terms of IQ point losses avoided, the order of benefits obtained by the decision rules is identical to that observed for the downward shifts in the blood lead distributions. The 500/400/- decision rule and the Voluntary Optimum show avoided IQ point losses in the first year of about 2.8 million and 1.9 million, respectively. It is noteworthy that the 2300/1200/20 and 2300/1200/- decision rules have slightly lower total avoided IQ point losses of about 1.4 million, but that the average IQ point loss per affected individual is almost 2 points, versus about 1.6 points per individual for the 500/400 and voluntary optimum rules.

The benefits in terms of avoided incidence of IQ < 70 deviates slightly from the avoided IQ point losses in that the Voluntary Optimum ranks slightly below the 2300/1200/20 and 2300/1200/- decision rules. This is in large part due to the effect of the larger residual tail in the Voluntary Optimum discussed previously coupled with the piece wise linear regressions used to estimate the incidence of IQ < 70 which has a higher probability at higher blood lead levels.

Similarly, in the avoided incidence of blood lead levels above 25 μg/dl (Exhibit 5-6), the general order is similar, but in this case the Voluntary Optimum falls below both the 2300/1200/20 and 2300/1200/- rules, as well as the -/1200/20 and -/1200/- rules. Again, this is the effect of the Voluntary Optimum including no high end paint abatements noted previously.

Exhibit 5-7 provides a summary of the resulting impact of the various decision rules on limiting the individual risk of children to elevated blood lead levels. As indicated there, it is estimated that in the baseline (no abatement) case, about 960,000 children in the first year cohort are born into homes where the predicted geometric mean blood lead levels are above 6.5 μg/dl. Assuming a GSD of 1.6 for these homes, the individual risk of exceeding 10 μg/dl is 18.0% or greater, of exceeding 15 μg/dl is about 4.76% or greater, and of exceeding 20 μg/dl is about 0.85% or greater. As shown in Exhibit 5-7, the 500/400/- decision rule eliminates all cases of homes where the expected blood lead GM is $\geq$ 6.5 μg/dl, which was the specific intent of this particular decision rule. The other decision rules result in approximately 600,000 to 880,000 of the baseline 960,000 children in the first model year being born into homes where paint, soil and dust levels imply GMs at or above 6.5 μg/dl.

Exhibit 5-8 shows the avoided incidence of neonatal mortality for the various decision rules. Most of the decision rules result in essentially identical benefits of avoiding 48 or 49 cases of neonatal mortality in the first year cohort. These neonatal mortality cases avoided result almost entirely from the required high end paint abatement in homes having bad condition lead paint[2]. The 500/400/- decision rule has a somewhat higher benefit of 75 cases avoided, owing to the need to perform additional high-end paint abatements beyond those for

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[2] The current model assumptions for neonatal mortality associate this adverse effect with the presence of any interior lead paint in the home. Since only high-end paint abatement eliminates all interior lead paint, only high-end paint abatement will provide the benefit of reduced incidence of neonatal mortality.

homes having bad condition in order to meet the more stringent dust level of 400 ppm. The Voluntary Optimum is notable in that no cases of neonatal mortality are avoided, since this option results in no high-end paint abatements being performed. (Note that in the baseline estimate there are about 330 neonatal deaths in the first year as a result of maternal exposure to lead paint.)

Exhibit 5-5. Summary of Avoided IQ Point Loss and Avoided Incidence of IQ < 70 by Decision Rule

Decision Rule	IQ Point Loss Avoided (First Model Year Cohort)	Affected Population of Children (First Model Year Cohort)[1]	Average IQ Point Loss Avoided (First Model Year Cohort)	Avoided Cases of IQ < 70
Baseline	0	0	0	0
Voluntary Optimum	1,912,011	1,482,732	1.34	5,434
Paint Condition Only	319,818	370,074	0.86	1,081
Soil = 2300 Dust = 1200 XRF = 20	1,404,490	714,261	1.97	5,308
Soil = 2300 Dust = 1200 No XRF value	1,402,677	708,989	1.98	5,305
Soil = 2300 No Dust Value XRF = 20	492,439	428,048	1.15	1,912
No soil value Dust = 1200 XRF = 20	1,318,269	683,096	1.93	4,877
Soil = 2300 No Dust value No XRF value	490,626	422,776	1.16	1,909
No soil value Dust = 1200 No XRF value	1,316,456	677,824	1.94	4,874
No soil value No dust value XRF = 20	321,631	375,346	0.86	1,084
Soil = 500 Dust = 400 No XRF value	2,751,452	1,736,524	1.58	8,823

[1] Total population in first model year cohort = 3,877,530

Exhibit 5-6. Summary of Avoided Incidence of Blood Lead > 25 μg/dl by Decision Rule

Decision Rule	Avoided Incidence of PbB > 25 μg/dl
Baseline	0
Voluntary Optimum	63,422
Paint Condition Only	14,744
Soil = 2300 Dust = 1200 XRF = 20	77,479
Soil = 2300 Dust = 1200 No XRF value	77,479
Soil = 2300 No Dust Value XRF = 20	30,736
No soil value Dust = 1200 XRF = 20	68,513
Soil = 2300 No Dust value No XRF value	30,736
No soil value Dust = 1200 No XRF value	68,513
No soil value No dust value XRF = 20	14,745
Soil = 500 Dust = 400 No XRF value	94,656

Exhibit 5-7. Summary of Children in First Year Cohort Remaining in Homes with Paint, Soil and Dust Lead Levels Implying Geometric Mean Blood Lead Levels ≥ 6.5 μg/dl

Decision Rule	First Year Cohort of Children Remaining in Homes with Predicted GM ≥ 6.5 μg/dl < 0.85% chance of PbB > 20 < 3.76 % chance of PbB > 15 < 18.0% chance of PbB > 10 (assuming GSD = 1.6)
Baseline	960,066
Voluntary Optimum	607,312
Paint Condition Only	883,301
Soil = 2300 Dust = 1200 XRF = 20	636,768
Soil = 2300 Dust = 1200 No XRF value	636,768
Soil = 2300 No Dust Value XRF = 20	861,764
No soil value Dust = 1200 XRF = 20	636,768
Soil = 2300 No Dust value No XRF value	861,764
No soil value Dust = 1200 No XRF value	636,768
No soil value No dust value XRF = 20	883,301
Soil = 500 Dust = 400 No XRF value	0

Exhibit 5-8. Summary of Avoided Incidence of Neonatal Mortality by Decision Rule

Decision Rule	Avoided Incidence of Neonatal Mortality (in First year Cohort of Children)
Baseline	0
Voluntary Optimum	0
Paint Condition Only	48
Soil = 2300 Dust = 1200 XRF = 20	49
Soil = 2300 Dust = 1200 No XRF value	48
Soil = 2300 No Dust Value XRF = 20	48
No soil value Dust = 1200 XRF = 20	49
Soil = 2300 No Dust value No XRF value	48
No soil value Dust = 1200 No XRF value	48
No soil value No dust value XRF = 20	48
Soil = 500 Dust = 400 No XRF value	75

5.4 VALUATION OF BENEFITS

In Section 5.3, above, the discussion of health damages associated with childhood lead exposure, and the benefits of reducing that exposure, focused on the incidence of adverse health effects in terms of blood lead distributions, IQ point losses, avoidance of IQ < 70, and neonatal mortality. To provide a basis for comparing the magnitude of the benefits resulting from paint, soil and dust abatements with the estimated cost of conducting those abatements, it is necessary to place a monetary value on the benefits. This section describes how these benefits have been monetized.

5.4.1 Valuing Lost IQ Points

Available economic research provides little empirical data for society's willingness to pay (WTP) to avoid a decrease in a child's IQ. As an alternative measure, it was assumed that IQ deficits incurred through lead exposure will persist throughout the exposed child's lifetime. Two consequences of this IQ decrement, representing a portion of society's full willingness to pay, are then considered: the decreased present value of expected lifetime earnings for the child, and the increased educational resources expended for a child who becomes mentally handicapped or is in need of compensatory education as a consequence of lead exposure. The value of foregone earnings is addressed in this section.

The reduction in IQ has a direct and indirect effect on earnings. The direct effect is straightforward -- lower IQs decrease job attainment and performance. Reduced IQ also results in reduced educational attainment, which, in turn, affects earnings and labor force participation. Note that these effects on earnings are additive since the studies used for this analysis have controlled for the direct and indirect effects separately.

Direct Effect of IQ on Wage Rate

Henry Aaron, Zvi Griliches, and Paul Taubman have reviewed the literature examining the relationship between IQ and lifetime earnings (USEPA 1984). They find that the direct effect, (schooling held constant) of IQ on wage rates ranged from 0.2 percent to 0.75 percent. Perhaps the best of these studies is Griliches (1977).[3] He found the direct effect of IQ on wage rates to be slightly more than 0.5 percent per IQ point. Because this value is roughly the median estimate of the USEPA review of the literature, it is the value used in this analysis.

Indirect Effect of IQ on Earnings

From Needleman et al. (1990) it is possible to estimate the change in years of schooling attained per one IQ point change. Their regression coefficients for the effect of tooth lead on

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3 Griliches used a structural equations model to estimate the impact of multiple variables on an outcome of interest. This method has conceptual advantages over other empirical estimates used in the literature because it successfully controls for the many confounding variables that can affect earnings.

achieved grade provide an estimate of current grade achieved. However, many of these children were in college at the time and are expected to achieve a higher grade level. Following Schwartz (1990a), after adjusting the published results for the fact that a higher percentage of children with low tooth lead were attending college, a 0.59 year difference in expected maximum grade achieved between the high and low exposure groups was estimated. It is assumed that educational attainment relates with blood lead levels in proportion to IQ. The difference in IQ score between the high and low exposure group was 4.5 points. By dividing 0.59/4.5 = 0.131, it suggests that the increase in lead exposure which reduces IQ by one point may also reduce years of schooling by 0.131 years.[4]

Studies that estimate the relationship between educational attainment and wage rates (while controlling for IQ and other factors) are less common. Chamberlain and Griliches (1977) estimate that a one year increase in schooling would increase wages by 6.4 percent. In a longitudinal study of 799 subjects over 8 years, Ashenfelter and Ham (1979) reported that an extra year of education increased the average wage rate over the period by 8.8 percent. Conservatively, we use a lower bound by assuming one year of additional schooling increases the wage rate by 6 percent. To arrive at the indirect effect of increased schooling, increased wages per IQ point is calculated using: (6 percent wage increase/school year) x (0.131 school years/IQ) = 0.786 percent increase in wages per IQ point.

There is one final indirect effect on earnings. Changes in IQ affect labor force participation. Failure to graduate high school, for example, correlates with participation in the labor force, principally through higher unemployment rates and earlier retirement ages. Lead is also a strong correlate with attention span deficits, which likely reduce labor force participation. The results of Needleman et al. (1990) relating lead to failure to graduate high school can be used to estimate changes in earnings due to labor force participation. Using the odds ratio from Needleman et al., it was estimated that a one IQ-point decrease would also result in a 4.5 percent increase in the probability of failing to graduate. Krupnick and Cropper (1989) provide estimates of labor force participation between high school graduates and non-graduates, controlling for age, marital status, children, race, region, and other socio-economic status factors. Based on their data, average participation in the labor force is reduced by 10.6 percent for persons failing to graduate from high school. Because labor force participation is only one component of lifetime earnings (i.e., earnings = wage rate X years of work), this indirect effect of schooling is additive to the effect on wage rates. Combining this estimate with the Needleman result of 4.5 percent increase in the risk of failing to graduate high school per IQ point, indicates that the mean impact of one IQ point loss is a (10.6% x 4.5%) = 0.477 % decrease in expected earnings from reduced labor force participation.

Combining the direct effect on wage rates of 0.5 percent with the two indirect effects (0.786% for less schooling and 0.477% for reduced labor force participation) yields a total of 1.76 percent decrease in earnings for every loss of one IQ point.

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[4] Following Schwartz (1990a), this analysis uses the Needleman (1990) to quantify the change in grade achievement from lead exposure.

Value of Foregone Earnings

In the next step to monetize intelligence effects, the percent earnings loss estimate must be combined with an estimate of the present value of expected lifetime earnings. Data on expected lifetime earnings as a function of educational attainment and sex was reported for the U.S. population in 1979 by the Bureau of the Census (USDOC 1983). Given the distribution of the 1979 population with respect to age, educational attainment, and sex, Census used age specific employment rates and average wage rates to estimate annual earnings as a function of age, sex and education. Assuming various rates of real wage growth (productivity effect) and discount factors, the annual earnings stream from age 18 to age 64 was collapsed to a series of estimates of the present value of lifetime earnings using an assumption of 1 percent real wage growth and a 7 percent discount rate. Men tend to earn more than women because of higher wage rates and higher labor force participation. However, for both men and women, expected lifetime earnings increase greatly with education.

The Census estimates were expressed in 1981 dollars and assumed that the age/education specific employment and average wage rates would remain constant over time. A number of issues must therefore be addressed in updating the Census estimates to 1990 dollars. First, educational attainment has changed since 1979, with a greater proportion of the population attending college, especially a greater proportion of women. Second, wage rates have increased both due to productivity effects (real wage growth) and inflation. Third, age-specific employment rates may have changed. Women, in particular, are likely to have higher rates of labor force participation than in 1979.

In revising the Census estimates, the first issue was addressed by using more recent data on education. USDOC (1992) provides data on educational attainment for the 1991 population. For this analysis, data on the population over age 25 were used in order to remove the influence of those individuals too young to have completed schooling. The population data were used as weighting factors to derive a sex and education weighted average of expected lifetime earnings. So constructed, the weighted average adjusts the estimate based on 1979 data to current levels of educational attainment. Lifetime earnings were thus calculated to be $177,000 for the average work force participant. The next step in adjusting the earnings estimate is to apply an adjustment for wage growth to update from 1981 to 1990 dollars. The Bureau of Labor Statistic's Employment Cost Index rose from a level of 67.2 in 1981 to 105.4 in 1990, an increase of about 57 percent. Updating the average lifetime earnings to 1990 dollars yields a revised estimate of $277,616.

While more recent age, sex, and education-specific employment rates could be used to re-estimate labor force participation, a complete analysis would require steps to dampen the effects of cyclical unemployment. Such an exercise would require considerable effort and is beyond the scope of this analysis. To the extent that labor force participation has increased for specific groups since 1979, the adjusted value presented here underestimates the true expected lifetime earnings. For example, if the percentage of female children eventually joining the permanent workforce is greater than the percentage of women over age 25 that worked in

1979, the expected lifetime earnings of female children would be greater than estimated in this analysis.

Note that use of earnings is an incomplete measure of an individual's value to society. Those individuals who choose not to participate in the labor force for all of their working years must be accounted for, since the lost value of their productive services may not be accurately measured by wage rates. The largest group are those who remain at home doing housework and child rearing. Also, volunteer work contributes significantly to social welfare and rates of volunteerism tend to increase with educational attainment and income.[5] If the opportunity cost of non-wage compensated work is assumed to be the average wage earned by persons of the same sex, age, and education, the average lifetime earnings estimates would be significantly higher and could be approximated by recalculating the tables using full employment rates for all age/sex/education groups. To be conservative, only the value of lost wages is considered in this analysis.

The adjusted value of expected lifetime earnings obtained above is a present value for an individual entering the labor force at age 18 and working until age 64. Because a lead-induced IQ decrement occurs in infancy or childhood, the $277,616 figure must be further discounted to the specific age at which the health effect is measured and adjusted for the probability that the infant would survive to age 18. For an infant less than one year old, the present value of lifetime earnings discounted at seven percent at age 18 and adjusted for survival would be $80,587. Combining this value with the estimate of percent wage loss per IQ point yields: $80,587 x 1.76 percent loss/IQ point = $1,414 per lost IQ point.

5.4.2 Valuing Increased Educational Resources

There are two categories of increased educational resources needed as a result of lead exposure. First, lead exposure results in an increase in the number of children with IQs less than 70 (note that IQ is not measured until age 7). As these children grow older, they will need an education program tailored to the mentally handicapped. In addition, some children whose blood lead is greater than 25 μg/dl will need additional instruction while attending school later in life.

Children with IQs Less than 70

To value the reduction in the number of infants with IQs less than 70, the reduction in education costs were measured - a clear underestimate of the total benefits.[6] Kakalik et al. (1981), using data from a study prepared for the Department of Education's Office of Special Education Programs, estimated that part-time special education costs for children who remained in regular classrooms cost $3,064 extra per child per year in 1978. Adjusting for changes in the GNP price deflator yields an estimate of $6,318 per child in 1990 dollars. For

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5 Statistical Abstract of the United States, 1986. Table No. 651, p. 383.

6 The largest part of this benefit is the parents' willingness to pay to avoid having their child become mentally handicapped, above and beyond the increased educational costs.

the calculations, this incremental estimate of the cost of part-time special education was used to estimate the cost per year per child needing special education as a result of impacts of lead on mental development. Costs would be incurred from grades 1 through 12. Discounting future expenses at a rate of 7 percent yields an expected present value cost of approximately $33,346 per child (assuming compensatory education begins at age 7 and continues through age 18). Note that this is an underestimate of the cost, since Kakalik et al. measured the increased cost to educate children attending regular school -- not a special education program.

Children with Blood Lead Levels > 25 μg/dl

When calculating the cost of compensatory education, three relatively conservative assumptions were made. First, it is assumed that no children with blood lead levels below 25 μg/dl would require compensatory education later in life. This is conservative since many studies show cognitive effects at 15 μg/dl. Second, it is assumed that only 20 percent of the children above 25 μg/dl would be severely affected enough to require and receive some compensatory education. Third, based on several follow-up studies that showed cognitive damage persists for three years or more, even after blood lead levels are lowered, it is assumed that each child who needed compensatory education would require it for three years (age 7 through 9).

For this analysis it is assumed 20 percent of the children with PbB > 25 μg/dl will receive compensatory education for three years, but after that, will not.[7] The Kakalik et al. (1981) estimate of part-time special education costs for children who remained in regular classrooms is also used to estimate the cost of compensatory education for children suffering low-level cognitive damage. As indicated above, adjusting for changes in the GNP price deflator yields an estimate of $6,318 per child in 1990 dollars. Discounting future costs at a rate of 7% annually yields a present value estimate of $11,048 in 1990 dollars.

5.4.3 Valuing Neonatal Mortality

The value of avoiding a statistical death used in this analysis is $2 million. This value is based on the lower estimate of a range of values provided in a review of studies quantifying individual's willingness to pay to avoid risks to life by Fisher et al. (1989). The Fisher et al. lower bound estimate of $1.8 million in 1986 dollars is adjusted for inflation and real income growth to 1992 dollars using the Gross Domestic Product (GDP) implicit price index.

5.5 COMPUTING BENEFITS FOR FULL MODEL PERIOD

In Chapter 3, we provided a detailed description of the procedures used to inflate the results obtained for the first year of the modeling time frame to arrive at the results for the overall 50 year modeling period. As discussed there, the incidence of adverse effects (such as

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7 See U.S. EPA (1986) for more detail on the data sources and the nature of the assumptions made to quantify this benefit category.

number of IQ points lost, cases of IQ < 70) obtained in the first model year in homes with lead paint are multiplied by a factor of 48.65, and by a factor of 99.60 for homes without lead paint to obtain the full 50 year incidence. The benefits of the various decision rules expressed in terms of avoided incidence of these effects can also be determined for the full model period by applying these factors to the avoided incidence calculated for the first model year in lead paint and non-lead paint homes.

To estimate the total value of the benefits over the full 50 year time frame, a similar pair of multipliers is applied to the value of the benefits obtained for the abatements performed in the first model year. The expression for computing the total benefits is similar to that given in Chapter 4 for computing total costs:

$$_T = \sum_{i=1}^{50} \frac{(AI_i) \bullet (V_1^*)}{(1+r)^{i-1}} \qquad \text{Equation (5-4)}$$

where:

V_t is the total value of the benefits

AI_i is the avoided incidence of the specific effect of concern;

$_1^*$ is the undiscounted unit value of the benefit in 1990 dollars, adjusted for additional expected children in homes getting abated;

r is the discount rate, here 7%.

The adjustment for additional expected children noted above that is included in the undiscounted unit value of the benefits is included in recognition of the potential benefits to future children born into those homes after the abatement is performed in response to the first births in those homes. As noted in Chapter 3, for each "first born" child in a home, there is an expected number of an additional 1.55 children in that same home over a subsequent 49 year period. Therefore, for each $1.00 in benefits for the first born child, an additional, undiscounted $1.55 in benefits is expected for the abatement performed on that home (i.e., this would be the value if those additional children were born in the same year as the first child). To account for the expectation that those additional children will be born at some later time, it is necessary to discount that amount. Discounting that additional $1.55 over the ensuing 50 years with a 7% discount rate, and taking the average of those discounted values results in an estimated additional benefit of approximately $0.50 for each $1.00 in first year benefits. Therefore, the undiscounted unit benefit cost provided in Section 5.4 are multiplied by 1.5 for inclusion in Equation 5-4 , above.

Using procedures similar to those described in Chapter 3, the multipliers obtained are 8.80 for homes with lead paint, and 12.48 for homes without lead paint. That is, the total value of the benefits is obtained by applying these multipliers to the undiscounted unit value of the monetized benefit calculated for the abatements performed in the first model year.

5.6 RESULTS OF MONETIZED BENEFITS

Exhibit 5-9 provides a summary of the total monetized benefits for the various decision rules considered over the full modeling period. As indicated by the values shown there, the order of the decision rules based on total monetized benefits is similar to the order obtained from consideration of changes in the blood lead distribution and avoided IQ point losses.

The largest benefits, totaling $66.7 billion, are achieved by the 500/400/- decision rule, followed by the Voluntary Optimum at $48.2 billion. The benefits for the 2300/1200/20 and 2300/1200/- rules have nearly identical benefits of $35.0 and $34.9 billion, respectively. Following these closely are the -/1200/20 and -/1200/- rules with benefits of $33.0 and $32.9 billion. Considerably lower total benefits are estimated for the 2300/-/20 and 2300/-/- rules, each with approximately $11.2 billion. Lastly, the -/-/20 and the paint condition only rules are estimated to produce total benefits of approximately $7.4 and $7.3 billion, respectively.

Exhibit 5-10 displays the relative contribution of the monetized value of each of the categories of benefits based on the first model year abatements for each decision rule. The relative contributions of the benefits categories are comparable for the entire modeling period.

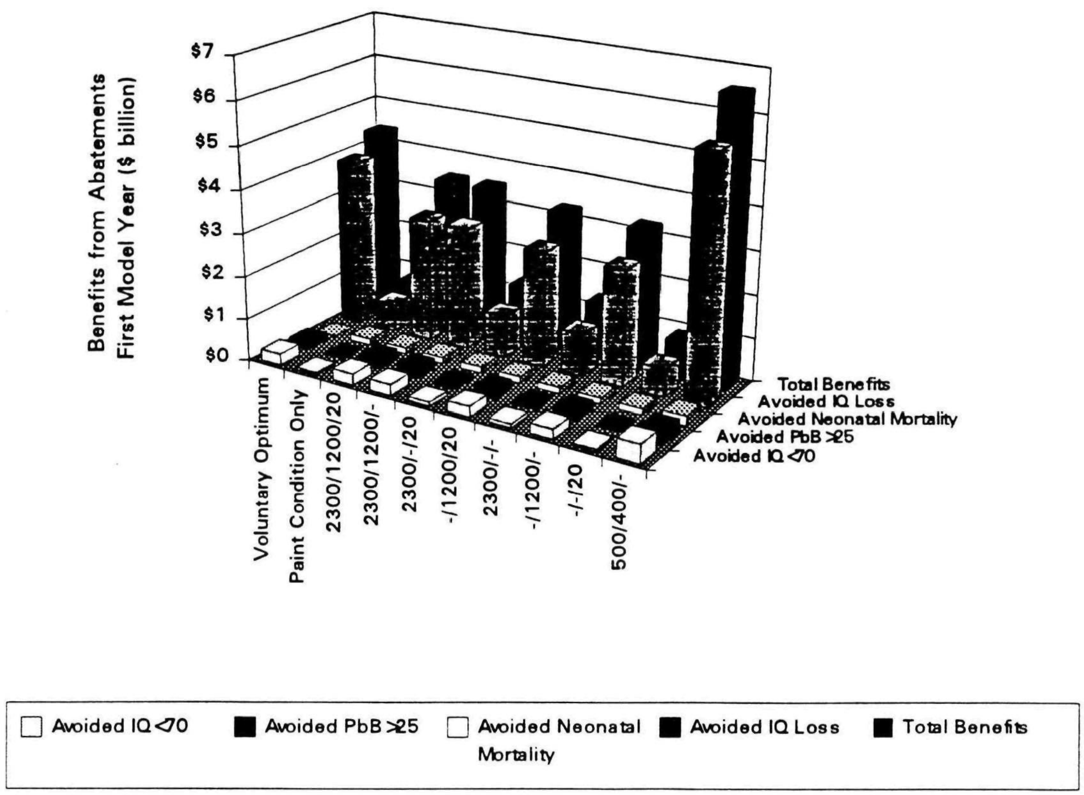
By far, the major contribution to the value of the benefits derives from the avoided loss of IQ points. For all of the decision rules, this component of the benefits contributes between 75% and 90% of the value of the benefits. The contributions of the avoided incidence of IQ < 70 and of blood lead levels > 25 μg/dl are comparable for each decision rule, generally contributing between 5% and 7% of the total benefits each.

The most variable contributor to the value of the benefits is avoided neonatal mortality. Except for the Voluntary Optimum and the 500/400/- decision rules, the monetized value of these benefits are comparable, approximately $140 million for the first year. For the Voluntary Optimum, neonatal mortality avoidance makes no contribution, while for the 500/400/- rule the value is about $220 million. Excluding the voluntary optimum, the avoided neonatal mortality benefits as a percentage of the total are lowest for those decision rules with the lowest total benefits, and highest for those with the lowest benefits. For example, in the Paint Condition only rule, the first year benefits are estimated to be about $890 million, and the neonatal mortality benefit at $138 million comprises about 16% of the total. By contrast, the 2300/1200/20 rule has total first year benefits of $3.5 billion, of which neonatal mortality at $141 million is only 4% of that total. For the 500/400/- rule, where the total first year benefits are highest at $6.6 billion, and the neonatal mortality is also highest among all rules at $220 million. However, as a percent of the total, these benefits constitute only about 3.3% for the 500/400/- rule.

Exhibit 5-9. Summary of Monetized Value of Benefits for Full Modeling Time Frame by Decision Rule

Decision Rule	Value of Benefits over Full Modeling Time Frame ($ Million)
Voluntary Optimum	$48,190
Paint Condition Only	$7,319
Soil = 2300 Dust = 1200 XRF = 20	$34,984
Soil = 2300 Dust = 1200 No XRF value	$36,920
Soil = 2300 No Dust Value XRF = 20	$12,249
No soil value Dust = 1200 XRF = 20	$33,009
Soil = 2300 No Dust value No XRF value	$11,186
No soil value Dust = 1200 No XRF value	$32,949
No soil value No dust value XRF = 20	$7,383
Soil = 500 Dust = 400 No XRF value	$66,688

Exhibit 5-10. Distribution of Monetized Benefits by Category for First Model Year Abatements.



6. BENEFIT-COST ANALYSIS

The objective of this chapter is to evaluate alternative sets of criteria which are expected to induce abatements of lead-contaminated soil, dust, and paint. These sets of criteria are called decision rules. For paint, its condition is taken as the primary criterion. For soil and dust, the criteria, called hazard levels, are expressed as concentrations of lead. This chapter also considers the possibility of making levels of lead contamination in paint a criterion for inducing abatement.

6.1 BASIS FOR EVALUATION

The two previous chapters have presented the costs and benefits of different types of abatements applied to homes with varying levels of lead in soil, dust, and paint and with paint in varying conditions. While benefits and costs are of independent interest, considering benefits or costs alone does not permit an evaluation of economic efficiency. On the contrary, it is not unusual for the decision rule generating the greatest benefits to have the highest costs, possibly even costs that exceed the benefits. It is also not unusual for the rule having the least costs to generate very small benefits. To produce significant benefits it may be necessary to expend significant resources.

To determine which circumstances are the ones that warrant a significant expenditure of resources requires that the benefits and costs be considered in tandem. Considering them in the form of net benefits (benefits minus costs) provides a basis for determining whether society will be better off by implementing any particular decision rule. Comparing different decision rules on the basis of their respective net benefits provides a means for identifying the best opportunities to improve economic efficiency. For this benefit-cost analysis, net benefits were calculated for thousands of different combinations of hazard levels for soil, dust, and paint.[1] This chapter focuses its attention on the decision rules that generate the highest net benefits.

6.2 ALTERNATIVE DECISION RULES

The abatement choices made under different decision rules in this analysis can be characterized in terms of differences in the information that the public is assumed to have. At one extreme, the public is assumed to have access to the same information that was used in this analysis: the blood lead levels expected among children if abatement does not take place; the blood lead reductions achievable from different abatement scenarios; the monetary values of these blood lead reductions; the cost of the alternative abatement approaches; and the levels of lead in soil, dust, and paint and the condition of paint in the home. At the other extreme, all households are assumed to know lead levels and paint condition but only the households that are

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[1] There are 14,972 different combinations of 30 soil concentrations, 20 dust concentrations, and 22 paint concentrations. Each combination constituted a potential decision rule in the benefit-cost analysis. Two other decision rules were also considered, a "voluntary optimum" and a qualitative hazard level based on paint condition, bringing the total to 14,974 different decision rules considered.

expected to abate (since their levels exceed candidate hazard levels and/or their paint is in bad condition) have the set of information necessary to choose the abatement alternative that yields the highest net benefits. Implicitly this assumes an ability to calculate benefits and costs for abatement alternatives. However, such a calculation by households may not actually be necessary. In practice, any household that chooses to abate will need to seek guidance regarding the combination of soil, dust, and point abatements that is appropriate to its circumstances.

6.2.1 Voluntary Optimum Decision Rule

The first decision rule considered in this analysis generates the highest net benefits of all decision rules evaluated. It serves as the benchmark against which all alternative decision rules can be judged. This decision rule is called the voluntary optimum because it is based upon households' determining which abatement alternative generates the highest net benefit and their voluntarily choosing to undertake that optimal abatement. Decisions under the voluntary optimum are assumed to draw upon sufficient information to determine whether it is optimal to abate and if so, to choose the optimal abatement alternative. In subsequent decision rules, households are assumed to have less information and therefore less leeway to choose on their own, instead being induced by EPA's hazard levels to initiate abatements of certain types. The evaluation of the voluntary optimum indicates that a substantial number of households would find it in their vested interest to have their homes abated.[2]

Examples

To illustrate the implications of allowing households to choose their abatements this way, examples for particular households are presented in Exhibit 6-1. Home A has a mean concentration of lead in soil of 8,800 ppm, mean concentration of interior dust of 1,100 ppm, and lead-based interior paint that is in damaged condition and has an XRF reading of 11. Relevant choices for this house are: high-end paint abatement, low-end paint abatement, high-end soil abatement, low-end soil abatement, recurrent dust abatement, four combined abatements (high-end paint abatement and high-end soil abatement, high-end paint abatement and low-end soil abatement, low-end paint abatement and high-end soil abatement, low-end paint abatement and low-end soil abatement). Nonrecurrent dust abatement is not a viable option because paint and soil would remain sources of lead contamination.

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2 The gross benefits considered by each household were assumed to include not only the private benefits accruing to that household from current and future members but also the social benefits accruing to any household living in the home in the 50 years after the birth of the child that is triggering the abatement decision. Based upon a 7% discount rate, a substantial portion of the benefits from abatement, approximately 69%, are associated with protecting the first child alone. (For households having additional children, the private proportion of the social benefits will be higher.) In many cases, net benefits can be positive when only this portion of the benefits is compared to costs. Where that is not the case, there is also the prospect that the homeowners can recoup all or part of their abatement costs in an increased value of the home at the time of sale. This increased value may stem from the possibility that the new owner places a premium on having a lead-abated home, from the spillover improvements in the home that come from certain types of abatement (such as the aesthetic improvements that come from high-end paint abatement), or from both.

Under the voluntary optimum, home A chooses low-end soil abatement, which generates net benefits of $3,607. High-end soil abatement would generate higher benefits but disproportionately higher costs, so much so that the resulting net benefits are negative. The damaged condition of paint does not justify paint abatement. Consequently, paint abatement options generate negative net benefits, with the exception of combining low-end soil and low-end paint abatement. This combination results in positive net benefits but lower than what can be accomplished by low-end soil abatement alone since low-end paint abatement generates negative net benefits.[3]

After the abatement, soil levels would be 500 ppm, predicted dust levels are still above 1000 ppm since paint contamination has not been abated, and some soil contamination still exists. No further abatements appear to be warranted. As indicated above, undertaking paint abatement in addition to soil abatement generates negative net benefits. Additional abatement directed at the remaining dust, through recurrent dust abatement, also generates negative net benefits.

Home B has approximately the same dust contamination as home A (1000 ppm) but no lead-based paint and soil contamination of only 100 ppm. The only relevant abatement choices for this home are recurrent and nonrecurrent dust. The former is not needed since there is no known major source of lead. Negative net benefits for recurrent dust abatement reflect this phenomenon. Instead, nonrecurrent dust abatement is chosen since it generates positive net benefits of $2,614. After abatement, this home will have dust and soil levels of 100 ppm.

Home C provides an example where dust abatement is optimal even where lead contamination is present in soil and damaged interior paint as well as in dust. This example illustrates the substitutability among lead abatements for different media. For each of the three media (soil, dust, and paint), some form of abatement could be selected that produces positive net benefits. These are low-end paint abatement, high-end soil abatement, recurrent dust abatement, and nonrecurrent dust abatement. Choosing the latter generates the highest net benefits, $2,555, more than twice the net benefits from the next best alternative - low-end paint abatement. Being able to exploit the substitutability by choosing the one with the highest net benefits is one key to the high net benefits of the voluntary optimum. Inducing households to meet medium-specific targets can reduce the achievable net benefits. For example, by setting a soil hazard level of 1100, it is assumed that the owner of home C would be induced to undertake high-end soil abatement since this is the only means for getting below this specific hazard level.

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3 The net benefits of combining low-end soil and low-end paint abatements are higher than the sum of each of these abatements alone because the blood lead reductions implied by a given change in a lead source are not constant. They are lower at higher levels.

Exhibit 6-1

Examples of Abatement Choices Under the Voluntary Optimum Decision Rule

Home	Soil ppm	Dust ppm	Paint mg/cm²	Condition	Net Benefits ($1990)										Selected Abatement
					HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NRD	
A	8800	1100	11	Damaged	(9336)	(2203)	(9364)	3607	(6683)	(13963)	(2466)	(10520)	2356	N/A	Low-end Soil (LS)
B	100	1000	0	Intact	N/A	N/A	N/A	N/A	(4312)	N/A	N/A	N/A	N/A	2614	Non-Recurrent Dust (NRD)
C	1100	3300	5	Damaged	(4046)	1208	157	(1587)	92	(6145)	(8062)	(1689)	(3240)	2555	Non-Recurrent Dust (NRD)
D	0	200	20	Damaged	(6227)	55	N/A	N/A	(7307)	N/A	N/A	N/A	N/A	N/A	Low-End Paint Abatement (LP)
E	800	1200	1	Intact	(8349)	(2144)	(3055)	(5181)	(4138)	(12097)	(14015)	(5782)	(7912)	(161)	None

Key

HP = High-End Paint Abatement
LP = Low-End Paint Abatement
HS = High-End Soil Abatement
LS = Low-End Soil Abatement
RD = Recurrent Dust Abatement

HP/HS = High-End Paint Abatement and High-End Soil Abatement
HP/LS = High-End Paint Abatement and Low-End Soil Abatement
LP/HS = Low-End Paint Abatement and High-End Soil Abatement
LP/LS = Low-End Paint Abatement and Low-End Soil Abatement
NRD = Nonrecurrent Dust Abatement

The designation of N/A for net benefits means that either the associated abatement is not applicable because no lead is present from the source abated (i.e., soil, dust, or paint) or that the initial level of lead is at or below the assumed post-abatement level. In either case, abatement of the source produces no benefits.

In the voluntary optimum, paint abatement is the optimal choice in only a few homes. Home D illustrates the special circumstances where low-end paint abatement was the optimal choice. Essentially, paint abatement is the best choice because neither soil abatement nor dust abatement is relevant. There is little or no contamination in these media; therefore no substitutability among media to abate can be exploited. Paint abatement is also justified because the XRF reading is so high. The latter results in expected damages from pica, which is assumed to have a 25% chance of being exhibited by the first child born into this home after abatement, that are large enough to justify abatement. The net benefits from low-end paint abatement are small but positive.

The final example, home E, shows that choosing not to abate can also be an optimal choice, even when there is lead contamination in each of the three media - 800 ppm in soil, 1200 ppm in dust, and a maximum XRF of 1 for interior paint. It is optimal not to abate because each abatement alternative has negative net benefits. This outcome further underscores how other decision rules besides the voluntary optimum lead to lower net benefits. For example, suppose that a decision rule were constructed based upon a soil level of 800 ppm and that the owner of home E is induced to abate because this level has been set by EPA. At best, this homeowner could expect to achieve only negative net benefits, -$3,055. In the aggregate, if there are a large number of homeowners in similar circumstances, this particular hazard level can lead to a substantial portion of the induced abatements having negative net benefits. Consequently, how well a particular set of hazard levels performs relative to others in terms of aggregate net benefits depends on how well it can avoid inducing abatements in homes where they are not warranted.

Results for the Voluntary Optimum

Over the course of the 50 years of births modeled in this analysis, 45 million abatements would be initiated under the voluntary optimum decision rule. As indicated in Exhibit 6-2, approximately 99% are nonrecurrent dust abatements. Initial lead concentrations in the dust range from 200 to 5,900 ppm. Lead concentrations in soil are less significant, ranging from 100 to 1,100 ppm. Low-end soil abatements account for a little more than 1%. In these homes, soil concentrations, which are much higher than for the homes receiving nonrecurrent dust abatement, range from 3,000 to 8,800 ppm. Dust concentrations, which can be affected indirectly by soil abatement, range from 1,100 to 5,800. The small remaining fraction of abatements entail low-end paint abatement. As anticipated from the example cited above, the interior XRF readings are high (20 to 22) and the dust and soil levels for the paint-abated homes are low. Among the homes where the choice is made not to abate, the maximum contamination levels can be as high as 3,100 ppm for soil, 2,500 ppm for dust, and an XRF of 22 for paint.

The present discounted value of the net benefits under the voluntary optimum is approximately $34 billion. These results imply average discounted benefits of $1,067, average discounted costs of $308, and average discounted net benefits of $759. The discounted net benefits per home range from a low of $11 to a high of $13,126.

These figures do not reflect the testing and inspection costs that are a prerequisite to determining what, if any, abatement is justified in a home. To determine lead levels in soil and dust in all homes where a birth is imminent and paint levels in homes where a birth is imminent, the undiscounted cost of testing is $713.

Ideally this cost would be included in the benefit-cost calculation made for each house. While the testing costs have to date not been included, subtracting the total testing costs from the total net benefits provides a sufficient evaluation given certain assumptions. Excluding testing costs from the individual abatement decision could have a significant effect on the gross benefits but possibly not the number of abatements. Given estimated testing costs of $713 per home, it is assumed that some homeowners would not choose to test if the expected pay-off from the test (the likelihood of a positive test result times the net benefit from the best abatement choice) is less than the cost of testing. Following this kind of logic in the modelling would likely lower the testing costs, the number of abatements, and the benefits and costs. However, for homeowners who choose to test without regard to the expected pay-off, the number of abatements would not change. When the net benefits of abatement are positive, abatement will be initiated. The testing costs are sunk costs that do not affect the decision to abate. In this situation, the number of abatements and the gross benefits may not be too different from that estimated currently for the voluntary optimum although the net benefits will.

By subtracting the total testing costs of $24 billion from the total net benefits, it is possible to provide an estimate of net benefits under these circumstances. The resulting overall net benefits of $10 billion from the voluntary optimum are still substantial.

Exhibit 6 - 2
Voluntary Optimum

Induced Abatement	Stategy Selected	Total 50-Year Benefits ($million)	Total 50-Year Costs ($million)	Total 50-Year Net Benefits ($million)	Total Number of Abatements (1000s)	Proportion of Abatements	Number of Abatements With Negative Net Benefits	Minimum Individual Net Benefits	Maximum Individual Net Benefits	Minimum Soil Level (ppm)	Maximum Soil Level (ppm)	Minimum Dust Level (ppm)	Maximum Dust Level (ppm)	Minimum Interior Paint (mg/cm²)	Maximum Interior Paint (mg/cm²)
No	None	0	0	0	0		0	0	0	0	3,100	0	2,500	0	22
	LS	2,789	1,992	797	577	1.28%	0	670	8,843	3,000	8,800	1,100	5,800	0	11
	LP	26	26	0	21	0.05%	0	47	55	0	100	200	400	20	22
	NRD	45,375	11,878	33,497	44,567	98.68%	0	11	13,126	0	1,100	200	5,900	0	13
Total:		48,190	13,896	34,294	45,165		0								

Abatement Codes

HP = High Paint Abatement
LP = Low Paint Abatement
HS = High Soil Abatement
LS = Low Soil Abatement
RD = Recurrent Dust Abatement

HP/HS = High Paint, High Soil Abatements
HP/LS = High Paint, Low Soil Abatements
LP/HS = Low Paint, High Soil Abatements
LP/LS = Low Paint, Low Soil Abatements
NR D = Nonrecurrent Dust Abatement

6.2.2 Decision Rules Based Upon Induced Abatements

Since the current rate of abatement does not appear to be as great as that implied by the voluntary optimum, it is reasonable to wonder what interventions are necessary to induce homeowners to initiate abatement. Section 403 of TSCA proposes hazard levels that have the potential to serve as a means of inducing abatement. The strong assumption made in this analysis is that owners of homes where any given hazard level is exceeded and where a child is about to be born will be induced to abate.

To evaluate a particular set of candidate hazard levels that EPA might consider setting, this analysis characterizes these levels as restrictions to the behavior modelled under the voluntary optimum. For example, suppose that the Agency were to set a soil hazard level of 1100 ppm and a dust hazard level of 1200 ppm. Using these criteria as constraints on each household's decision of whether and how to abate, this analysis identifies the highest net benefits achievable while adhering to EPA's hazard levels. Relative to the pure voluntary optimum, this circumstance reflects a constrained optimization. Therefore, the net benefits will be lower since households may be induced by EPA's guidance to make abatement choices which had lower or even negative net benefits under the voluntary optimum. Referring to Exhibit 6-1 again, home E would be induced by this set of hazard levels, particularly the 1200 ppm threshold for dust, to undertake dust abatement even though the net benefits are negative.

Since EPA's promulgation of hazard levels does take the form of guidance for most households and does not bind any household to adhere to them, the circumstances of the individual household's decisionmaking are assumed to be different in this constrained optimization that they were under the voluntary optimum. The difference can be described in terms of differences in the information households are assumed to have about the benefits and costs of lead abatement. Since information is costly to the household, the assumption of perfect information being available to the household is a strong one. By providing guidance to households in the form of hazard levels at which abatement should be undertaken, EPA can lower the actual information costs for the household abatement decision. However, rather than providing each household with perfect information, the hazard levels promulgated by EPA would serve as general guidance and not the type of information that allows each household to determine exactly what is best.

The result is that some households will make the same abatement choice as they would if they had perfect information, some will be induced to choose a form of abatement that provides lower net benefits, and some will be induced to abate when they would have chosen not to under the voluntary optimum. Taking the candidate hazard levels mentioned (soil = 1100 ppm and dust = 1200 ppm), these outcomes can be illustrated using the homes highlighted in Exhibit 6-1. Home A exceeds the soil hazard level. No change in behavior is necessary since low-end soil abatement, which was chosen under the voluntary optimum, is sufficient to reduce soil contamination below this threshold. Home C exceeds both the soil and dust thresholds. The optimal choice under the voluntary optimum, nonrecurrent dust abatement, does not address soil contamination. Consequently, the best choice that allows getting below both thresholds is high-end soil abatement, which has positive net benefits of $157 but these are lower than those achievable through nonrecurrent dust abatement ($2,555). Finally, the example of home E, where no abatement is optimal under the voluntary optimum, would be induced to choose nonrecurrent dust abatement, with negative net benefits (-$161), to meet the dust hazard level.

Taken together, the overall net benefits for these three homes of selecting abatements are positive. For the full set of homes considered in this analysis, the overall net benefits of selecting abatements based upon a particular set of candidate could be positive or negative. Only by setting hazard levels specific to each house is it possible to replicate the voluntary optimum. Since it does not yet appear feasible for EPA to structure the hazard levels it promulgates this way, a simpler and more general set of hazard levels were assumed to be more likely.

One important objective of this analysis was to identify sets of hazard levels of different types which compromised least the net benefits achievable under the pure voluntary optimum. The sets of hazard levels, referred to as decision rules, are of four types. See Exhibit 6-3. The first type of decision rule addressed paint condition. It assumes that all homes with non-intact paint will undertake paint abatement. The second type of decision rule included this criterion as well as a hazard level for each of the three media that are addressed by this rule - soil, dust, and paint. In Exhibit 6-3, these are labeled "single-medium constrained." The third type of decision rule encompasses hazard levels for two media, as well as condition. The fourth type of decision rule addresses all three media and condition. Each of these will be considered in turn.

Exhibit 6-3
Taxonomy of Decision Rules

Decision Rules	Soil (ppm)	Dust (ppm)	Paint (XRF)	Paint Condition
Condition Constrained	---	---	---	Yes
Single-Medium Constrained	Yes	---	---	Yes
	---	Yes	---	Yes
	---	---	Yes	Yes
Two-Media Constrained	Yes	Yes	---	Yes
	Yes	---	Yes	Yes
	---	Yes	Yes	Yes
Three-Media Constrained	Yes	Yes	Yes	Yes

Note: A "Yes" indicates that a hazard level is fixed for that particular medium in the decision rule.

Qualitative Hazard Level for Paint Condition

The first type of decision rule targets the condition of paint only. Under this rule, only houses with non-intact paint are induced to abate. Exhibit 6-4 presents the benefit-cost results for this decision rule. The total number of abatements only reflect the abatement of homes with lead-based paint in bad condition. The abatement of other homes, which would be expected under the voluntary optimum, are not included, given the logic of this decision rule that only the qualitative hazard level will induce abatement. Also, in contrast with the voluntary optimum, certain homes are induced by the decision rule to undertake paint abatement even though this creates negative net benefits. Of the 7.1 million abatements induced by this decision rule, 6.7 million (95%) have negative net benefits. Overall, the net benefits for this decision rule were negative (-$17.3 billion).

Exhibit 6-4 also shows the distribution of abatements by category. Since the decision rule is specifically targeted at paint, only the paint abatement alternatives are chosen.[4] High-end paint is the optimal choice for 59% of the homes; low-end paint is the choice in 39% of the homes. Owners of other homes chose combinations of paint abatement and soil abatement, since these choices have higher net benefits than paint abatement alone. The numbers of high-end and low-end paint abatements with negative net benefits are approximately proportional to the total numbers of abatements associated respectively with each.

Exhibit 6-4 also presents the abatement-specific net benefits, both in aggregate and the range of undiscounted values for individual homes. These results underscore the difficulty with specifying an across-the-board rule. There are cases of positive net benefits for individual homes undertaking low-end paint abatement (where the maximum net benefits are $7,142), high-end paint abatement (where the maximum net benefit is $2,629) and combined low-end paint/low-end soil abatements (where the maximum net benefits are $2,356). However, the dominant outcome is that this decision rule entails substantial negative net benefits. Of the 7.1 abatements induced by this decision rule, 6.7 million (95%) generate negative net benefits.

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[4] Taken literally, a paint condition criterion requires abating pain in bad condition only. Neither paint abatement alternative used in this analysis is tailored particularly to abating deteriorating paint alone. Instead, high-end paint abatement entails complete and full abatement of interior lead-based paint and low-end paint abatement involves full abatement of windows only. As such, the costs and effectiveness of these alternatives are taken as proxies respectively for abatements addressing "extensive" and "limited" amounts of deteriorating paint.

Exhibit 6 - 4
Paint Condition Criterion

Induced Abatement	Stategy Selected	Total 50-Year Benefits ($ millions)	Total 50-Year Costs ($ millions)	Total 50-Year Net Benefits ($ millions)	Total Number of Abatements (1000's)	Proportion of Abatements	Abatements With Negative Net Benefits (1000's)	Minimum Individual Net Benefits ($)	Maximum Individual Net Benefits ($)	Minimum Soil Level (ppm)	Maximum Soil Level (ppm)	Minimum Dust Level (ppm)	Maximum Dust Level (ppm)	Minimum Interior Paint (mg/cm²)	Maximum Interior Paint (mg/cm²)
No	None	0	0	0	0		0	0	0	0	3,100	0	2,500	0	22
	HP	5,208	20,134	(14,926)	4,160	58.88%	4,027	(9,690)	2,629	0	2,200	0	5,900	1	22
	LP	1,456	3,517	(2,061)	2,774	39.27%	2,544	(2,657)	7,142	0	3,100	. 0	5,900	1	22
	HP/LS	564	943	(379)	114	1.61%	114	(8,514)	(2,466)	3,100	8,800	1,100	1,200	10	11
	LP/LS	91	74	17	16	0.00%	0	2,356	2,358	8,800	8,800	1,100	1,100	11	11
Total:		7,319	24,668	(17,349)	7,064		6,685								

Abatement Codes

HP = High Paint Abatement
LP = Low Paint Abatement
HS = High Soil Abatement
LS = Low Soil Abatement
RD = Recurrent Dust Abatement

HP/HS = High Paint, High Soil Abatements
HP/LS = High Paint, Low Soil Abatements
LP/HS = Low Paint, High Soil Abatements
LP/LS = Low Paint, Low Soil Abatements
NR D = Nonrecurrent Dust Abatement

Single Medium Hazard Levels

The effects of setting a hazard level for a single medium alone - for soil, dust, or paint - in addition to a qualitative hazard level for paint condition are considered in this section. While the intent of Section 403 is to set hazard levels for soil, dust, and paint, the results for these single-medium decision rules illustrate that the individual media make very different contributions to a three-media approach to addressing residential lead risks. As will be shown below, decision rules based upon two of the three individual media (soil and paint) lead to negative net benefits. The net benefits of the best dust hazard level are more than $20 billion higher than the net benefits of either the best soil or paint hazard levels.

For each medium, a wide array of candidate decision rules are considered. Choosing the best among these alternatives is based upon a comparison of net benefits. For soil, the benefit-cost results for thirty alternative hazard levels ranging from 100 ppm to 3,000 ppm are given in Exhibits 6-5 and 6-6. For paint, the results for twenty-two XRF readings from 0 to 21 are presented in Exhibits 6-7 and 6-8. For dust, the results for twenty alternative hazard levels ranging from 100 ppm to 2,000 are presented in Exhibits 6-9 and 6-10.

Given the framework of a single-medium decision rule combined with a paint condition criterion, a hazard level of 2,300 ppm for soil would achieve the highest net benefits but these are negative (-$17.2 billion). Separate analyses indicate that the paint condition criterion is responsible for the bulk of the negative net benefits. This finding was anticipated from the earlier results showing large negative net benefits from the previous decision rule involving paint condition alone.

The optimal hazard level for paint is an XRF reading of 20 mc/cm^2 but again the net benefits are negative (-$17.6 billion). While there are homes having XRF levels equal to or greater than 20 whose owners choose paint abatement under the voluntary optimum, their number was small (20,503) and they choose low-end paint abatement only. In contrast, the owners of more than 4 million homes choose to conduct high-end paint abatement because this decision rule combines the paint condition criterion with the single-medium paint hazard level. Almost 95% of the induced abatements have negative net benefits.

The best prospect among the single-medium decision rules is one based upon dust. A single hazard level of 1200 ppm for dust combined with the paint condition criterion generates net benefits of $3.3 billion. The net benefits are higher for the single dust hazard level because, unlike the previous two cases, there is greater leeway for homeowners to choose abatements with higher pay-off, especially but not exclusively, the two forms of dust abatement. Consequently, the accuracy of this decision rule in targeting homes with positive net benefits is higher. Of the 15.6 million abatements induced by this decision rule, only 46% entail negative net benefits.

Exhibit 6-5

Single Medium Hazard Levels: Soil

Decision Rules		Benefits ($ millions)	Abatement Costs ($ millions)	Net Benefits ($ millions)	Total Number of Abatements (1000s)	Induced Abatements With Negative Benefits (1000s)
Soil (ppm)	Nonintact Paint Abatement Recommended					
3,000	YES	9,983	27,241	(17,258)	7,750	7,154
2,900	YES	11,186	28,345	(17,159)	8,069	7,154
2,800	YES	11,186	28,345	(17,159)	8,069	7,154
2,700	YES	11,186	28,345	(17,159)	8,069	7,154
2,600	YES	11,186	28,345	(17,159)	8,069	7,154
2,500	YES	11,186	28,345	(17,159)	8,069	7,154
2,400	YES	11,186	28,345	(17,159)	8,069	7,154
2,300	YES	11,186	28,345	(17,159)	8,069	7,154
2,200	YES	14,645	33,471	(18,826)	10,139	9,224
2,100	YES	15,240	34,466	(19,226)	10,486	9,571
2,000	YES	15,240	34,466	(19,226)	10,486	9,571
1,900	YES	15,240	34,466	(19,226)	10,486	9,571
1,800	YES	15,240	34,466	(19,226)	10,486	9,571
1,700	YES	15,240	34,466	(19,226)	10,486	9,571
1,600	YES	15,571	34,896	(19,325)	10,649	9,734
1,500	YES	15,571	34,896	(19,325)	10,649	9,734
1,400	YES	15,750	35,403	(19,652)	10,761	9,845
1,300	YES	15,906	35,731	(19,824)	10,828	9,913
1,200	YES	16,864	37,862	(20,998)	11,445	10,530
1,100	YES	17,091	38,189	(21,098)	11,513	10,597
1,000	YES	17,441	38,547	(21,106)	11,586	10,606
900	YES	18,708	45,155	(26,447)	13,189	12,209
800	YES	18,708	45,155	(26,447)	13,189	12,209
700	YES	20,539	48,149	(27,611)	14,104	13,124
600	YES	20,628	49,131	(28,503)	14,320	13,340
500	YES	21,211	51,656	(30,444)	14,883	13,912
400	YES	31,968	88,648	(56,681)	16,922	16,722
300	YES	34,207	94,859	(60,651)	18,777	18,577
200	YES	37,582	111,203	(73,620)	23,259	23,059
100	YES	40,049	136,435	(96,386)	29,157	28,958

Exhibit 6-6

Single Medium Hazard Levels for Soil: Types of Abatement

Decision Rules		HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NR D
Soil (ppm)	Nonintact Paint Abatement Recommended	(1000s)	(1000s)	(1000s)	(1000s)	(1000s)	(1000s)	(1000s)	(1000s)	(1000s)	(1000s)
3,000	YES	4,160	2,716	0	686	0	0	114	0	74	0
2,900	YES	4,160	2,716	0	1,006	0	0	114	0	74	0
2,800	YES	4,160	2,716	0	1,006	0	0	114	0	74	0
2,700	YES	4,160	2,716	0	1,006	0	0	114	0	74	0
2,600	YES	4,160	2,716	0	1,006	0	0	114	0	74	0
2,500	YES	4,160	2,716	0	1,006	0	0	114	0	74	0
2,400	YES	4,160	2,716	0	1,006	0	0	114	0	74	0
2,300	YES	4,160	2,716	0	1,006	0	0	114	0	74	0
2,200	YES	4,160	2,716	0	3,076	0	0	114	0	74	0
2,100	YES	4,147	2,708	0	3,423	0	0	126	0	82	0
2,000	YES	4,147	2,708	0	3,423	0	0	126	0	82	0
1,900	YES	4,147	2,708	0	3,423	0	0	126	0	82	0
1,800	YES	4,147	2,708	0	3,423	0	0	126	0	82	0
1,700	YES	4,147	2,708	0	3,423	0	0	126	0	82	0
1,600	YES	4,147	2,708	163	3,423	0	0	126	0	82	0
1,500	YES	4,147	2,708	163	3,423	0	0	126	0	82	0
1,400	YES	4,126	2,694	163	3,534	0	0	147	0	96	0
1,300	YES	4,113	2,685	230	3,534	0	13	147	8	96	0
1,200	YES	4,113	2,685	230	4,151	0	13	147	8	96	0
1,100	YES	4,100	2,677	298	4,151	0	26	147	17	96	0
1,000	YES	4,086	2,668	371	4,151	0	40	147	26	96	0
900	YES	3,898	2,545	371	5,754	0	40	336	26	219	0
800	YES	3,898	2,545	371	5,754	0	40	336	26	219	0
700	YES	3,848	2,512	1,287	5,754	0	90	336	58	219	0
600	YES	3,807	2,485	1,287	5,970	0	90	377	58	246	0
500	YES	3,714	2,425	1,456	6,363	0	122	438	80	286	0
400	YES	3,426	2,237	9,858	0	0	847	0	553	0	0
300	YES	3,394	2,216	11,713	0	0	879	0	574	0	0
200	YES	3,263	2,131	16,195	0	0	1,010	0	659	0	0
100	YES	2,918	1,905	22,094	0	0	1,355	0	885	0	0

Exhibit 6-7
Single Medium Hazard Levels: Paint

Decision Rules		Benefits ($ millions)	Abatement Costs ($ millions)	Net Benefits ($ millions)	Total Number of Abatements (1000s)	Induced Abatements With Negative Benefits (1000s)
Paint (mg/cm²)	Nonintact Paint Abatement Recommended					
21	YES	7,383	25,013	(17,631)	7,164	6,786
20	YES	7,383	25,013	(17,631)	7,164	6,786
19	YES	7,870	27,605	(19,735)	7,920	7,542
18	YES	7,870	27,605	(19,735)	7,920	7,542
17	YES	7,870	27,605	(19,735)	7,920	7,542
16	YES	7,870	27,605	(19,735)	7,920	7,542
15	YES	7,870	27,605	(19,735)	7,920	7,542
14	YES	7,870	27,605	(19,735)	7,920	7,542
13	YES	7,870	27,605	(19,735)	7,920	7,542
12	YES	8,069	27,837	(19,767)	7,987	7,582
11	YES	8,118	28,300	(20,182)	8,123	7,718
10	YES	9,011	29,398	(20,387)	8,316	7,861
9	YES	10,502	33,541	(23,039)	9,238	8,784
8	YES	11,719	36,420	(24,701)	10,078	9,623
7	YES	12,170	37,767	(25,597)	10,471	10,016
6	YES	12,383	39,188	(26,805)	10,885	10,430
5	YES	16,558	42,626	(26,068)	11,888	10,712
4	YES	17,460	43,908	(26,448)	12,262	10,982
3	YES	17,574	45,164	(27,591)	12,628	11,348
2	YES	18,491	50,874	(32,382)	14,293	13,013
1	YES	19,479	60,588	(41,109)	17,126	15,846
0	YES	25,516	102,784	(77,268)	29,431	27,934

Exhibit 6-8

Single Medium Hazard Levels for Paint: Types of Abatement

Decision Rules		HP (1000s)	LP (1000s)	HS (1000s)	LS (1000s)	RD (1000s)	HP/HS (1000s)	HP/LS (1000s)	LP/HS (1000s)	LP/LS (1000s)	NR D (1000s)
Paint (mg/cm²)	Nonintact Paint Abatement Recommended										
21	YES	4,221	2,814	0	0	0	0	114	0	16	0
20	YES	4,221	2,814	0	0	0	0	114	0	16	0
19	YES	4,678	3,113	0	0	0	0	114	0	16	0
18	YES	4,678	3,113	0	0	0	0	114	0	16	0
17	YES	4,678	3,113	0	0	0	0	114	0	16	0
16	YES	4,678	3,113	0	0	0	0	114	0	16	0
15	YES	4,678	3,113	0	0	0	0	114	0	16	0
14	YES	4,678	3,113	0	0	0	0	114	0	16	0
13	YES	4,678	3,113	0	0	0	0	114	0	16	0
12	YES	4,719	3,139	0	0	0	0	114	0	16	0
11	YES	4,801	3,193	0	0	0	0	114	0	16	0
10	YES	4,841	3,219	0	0	0	0	190	0	65	0
9	YES	5,116	3,584	0	0	0	0	474	0	65	0
8	YES	5,624	3,915	0	0	0	0	474	0	65	0
7	YES	5,861	4,071	0	0	0	0	474	0	65	0
6	YES	6,112	4,234	0	0	0	0	474	0	65	0
5	YES	6,719	4,630	0	0	0	0	474	0	65	0
4	YES	6,945	4,778	0	0	0	0	474	0	65	0
3	YES	7,166	4,923	0	0	0	0	474	0	65	0
2	YES	8,174	5,580	0	0	0	0	474	0	65	0
1	YES	9,888	6,699	0	0	0	0	474	0	65	0
0	YES	17,332	11,560	0	0	0	0	474	0	65	0

Exhibit 6-9
Single Medium Hazard Levels: Dust

Decision Rules		Benefits ($ millions)	Abatement Costs ($ millions)	Net Benefits ($ millions)	Total Number of Abatements (1000s)	Induced Abatements With Negative Benefits (1000s)
Dust (ppm)	Nonintact Paint Abatement Recommended					
2,000	YES	26,227	26,656	(429)	12,370	6,753
1,900	YES	26,227	26,656	(429)	12,370	6,753
1,800	YES	26,227	26,656	(429)	12,370	6,753
1,700	YES	26,366	26,682	(317)	12,446	6,753
1,600	YES	28,342	27,218	1,124	13,351	6,762
1,500	YES	28,846	27,292	1,554	13,564	6,762
1,400	YES	29,669	27,557	2,112	13,954	6,803
1,300	YES	31,413	29,128	2,285	14,654	7,031
1,200	YES	32,945	29,646	3,299	15,602	7,114
1,100	YES	35,856	35,245	611	17,634	8,491
1,000	YES	37,227	37,354	(127)	17,909	8,781
900	YES	41,932	42,245	(313)	20,378	9,149
800	YES	43,145	44,872	(1,727)	21,019	9,625
700	YES	46,438	50,736	(4,298)	23,506	11,209
600	YES	49,416	53,947	(4,531)	25,962	12,168
500	YES	58,373	64,534	(6,161)	34,334	15,402
400	YES	63,230	70,785	(7,555)	43,883	19,756
300	YES	64,003	83,966	(19,963)	51,978	22,796
200	YES	71,579	121,989	(50,411)	63,963	30,267
100	YES	77,260	155,953	(78,693)	83,759	44,358

Exhibit 6-10

Single Medium Hazard Level for Dust: Types of Abatement

Decision Rules		HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NR D
Dust (ppm)	Nonintact Paint Abatement Recommended	(1000s)	(1000s)	(1000s)	(1000s)	(1000s)	(1000s)	(1000s)	(1000s)	(1000s)	(1000s)
2,000	YES	4,160	2,766	0	91	67	0	114	8	16	5,148
1,900	YES	4,160	2,766	0	91	67	0	114	8	16	5,148
1,800	YES	4,160	2,766	0	91	67	0	114	8	16	5,148
1,700	YES	4,160	2,766	0	91	67	0	114	8	16	5,224
1,600	YES	4,160	2,757	74	91	67	0	114	18	16	6,055
1,500	YES	4,160	2,757	74	91	67	0	114	18	16	6,268
1,400	YES	4,160	2,783	74	91	108	0	114	18	16	6,591
1,300	YES	4,177	2,740	74	411	202	0	114	18	16	6,903
1,200	YES	4,186	2,731	74	411	276	0	114	18	16	7,777
1,100	YES	4,289	2,627	74	411	1,581	0	172	9	16	8,455
1,000	YES	4,302	2,572	74	411	1,824	21	314	9	0	8,381
900	YES	4,397	2,516	222	411	2,811	35	314	28	0	9,642
800	YES	4,345	2,329	222	411	3,352	35	439	42	0	9,845
700	YES	4,449	2,239	148	1,028	4,281	45	439	32	0	10,845
600	YES	4,454	2,192	804	1,028	4,521	73	452	19	0	12,420
500	YES	4,469	2,087	967	3,098	5,359	73	541	19	0	17,721
400	YES	4,476	1,998	967	3,379	6,150	73	623	19	0	26,198
300	YES	4,125	1,894	2,092	0	10,772	1,026	0	19	0	32,050
200	YES	4,413	1,190	5,751	0	17,372	1,460	0	0	0	33,776
100	YES	4,167	692	8,983	0	22,126	2,205	0	0	0	45,587

Exhibit 6-11 provides greater detail on the benefit-cost results for a hazard level of 1200 ppm. Of the 15.6 million abatements associated with this decision rule, 8.1 million (52%) entail dust abatement alone (recurrent or nonrecurrent). It follows that the number of negative net benefits induced by this decision rule is a smaller percentage than was the case for either of the previous two decision rules, as indicated above.

Most of the successful targeting of homes for abatement is associated with the choice of nonrecurrent dust abatement. Of the 7.7 million homes induced to undertake recurrent dust abatement, 97% accrue positive net benefits. While these abatements are substantial, the two other media are also addressed. Furthermore, all of the high-end and low-end soil abatements generate positive net benefits, except when combined with paint abatement. The maximum net benefits per home are as high as $533 and $8,843 respectively for high-end and low-end soil abatement. All of the combined abatements involving high-end paint or high-end soil abatement have negative net benefits. Finally, the vast majority of the high-end and low-end paint abatements generate negative net benefits. Together, the net benefits of all high-end and low-end paint equal minus $17 billion. Again, this result was anticipated from the evaluation of the decision rule based on a paint condition criterion alone. Without the paint condition criterion, the net benefits of this decision rule would have been substantially higher.[5]

[5] It may be possible to improve the cost-effectiveness of paint abatement directed at non-intact paint and consequently improve the overall net benefits. Currently, the benefit-cost analysis assumes that all paint in a home will receive high-end paint abatement if there is non-intact paint that triggers abatement. More selective abatement of non-intact paint only could lower the costs of this abatement option without compromising the benefits significantly. Net benefits would improve as a result.

Exhibit 8 - 11
Single Medium Hazard Level: Dust = 1200

Induced Abatement	Stategy Selected	Total 50-Year Benefits ($ millions)	Total 50-Year Costs ($ millions)	Total 50-Year Net Benefits ($ millions)	Total Number of Abatements (1000's)	Proportion of Abatements	Abatements With Negative Net Benefits (1000's)	Minimum Individual Net Benefits ($)	Maximum Individual Net Benefits ($)	Minimum Soil Level (ppm)	Maximum Soil Level (ppm)	Minimum Dust Level (ppm)	Maximum Dust Level (ppm)	Minimum Interior Paint (mg/cm²)	Maximum Interior Paint (mg/cm²)
No	None	0	0	0	0	0.00%	0	0	0	0	3,100	0	1,200	0	22
Yes	HP	5,301	20,260	(14,960)	4,186	26.83%	4,053	(9,690)	2,629	0	2,200	0	5,900	1	22
	LP	1,385	3,461	(2,076)	2,731	17.50%	2,527	(2,557)	7,142	0	3,100	0	5,900	1	22
	HS	290	272	18	74	0.47%	0	533	533	1,100	1,100	3,300	3,300	5	5
	LS	1,892	1,420	472	411	2.63%	0	670	8,843	3,000	5,800	1,400	5,800	0	0
	RD	885	978	(92)	276	1.77%	202	(3,526)	1,694	100	1,200	1,400	3,600	6	13
	HP/LS	564	943	(379)	114	0.73%	114	(8,514)	(2,466)	3,100	8,800	1,100	1,200	10	11
	LP/HS	65	87	(22)	18	0.11%	18	(3,901)	(1,689)	1,100	1,200	2,500	3,300	5	11
	LP/LS	91	74	17	16	0.10%	0	2,356	2,356	8,800	8,800	1,100	1,100	11	11
	NR D	22,472	2,150	20,322	7,777	49.84%	200	(130)	13,126	0	800	1,300	5,900	0	10
Total		32,945	29,646	3,299	15,603		7,114								

Abatement Codes

HP = High Paint Abatement
LP = Low Paint Abatement
HS = High Soil Abatement
LS = Low Soil Abatement
RD = Recurrent Dust Abatement

HP/HS = High Paint, High Soil Abatements
HP/LS = High Paint, Low Soil Abatements
LP/HS = Low Paint, High Soil Abatements
LP/LS = Low Paint, Low Soil Abatements
NR D = Nonrecurrent Dust Abatement

Two-Media Hazard Levels

In this section, decision rules based upon hazard levels for two-media plus the paint condition criterion are evaluated. Under these circumstances, households have less leeway to optimize their abatement decisions than they did under the single-medium decision rules and much less than they did under the voluntary optimum. To satisfy recommendations based upon a two-media decision rule, such as the case where the soil hazard level is 2,300 ppm and the paint hazard level is an XRF of 20, it is assumed that any homeowner whose home exceeds either one of these thresholds would undertake the best abatement that makes it possible to go below both thresholds, as well as to meet the paint condition recommendation. In Exhibits 6-12 and 6-13, the results for the best cases of the three different combinations (soil/dust, soil/paint, dust/paint) are presented. The best cases are defined as the combinations having the highest net benefits.

As was the case under the single-medium decision rule, defining a hazard level for dust appears to be critical. The two combinations based upon a dust hazard level of 1200 ppm (soil = 2300 ppm and dust = 1200 ppm; dust = 1200 ppm and paint = 20 (XRF)) have the highest net benefits. As shown in Exhibit 6-12, the net benefits are over $3 billion. The two dust-based decision rules would induce abatement in 15.7 to 16.2 million homes and generate $33.0 to $34.9 billion in benefits. In contrast, the decision rule combining soil and paint hazard levels (soil = 2,300 ppm and paint = 20 mg/cm$_2$) has much lower benefits ($11 billion) and, accordingly, negative net benefits (-$17.4 billion).

The two rules based upon dust are approximately as accurate as the single-medium dust hazard level was in inducing abatements leading to positive net benefits. The percentage of abatements having negative net benefits is about 47% for the soil/dust combination or the dust/paint combination. As shown in Exhibit 6-13, the effectiveness of these two combinations stems from their being able to exploit nonrecurrent dust abatement, which is not a feasible alternative when the hazard levels are based upon soil and paint.

For all three combinations, the paint condition criterion creates a tremendous burden. This outcome is illustrated for the soil and dust combination, which has the highest net benefits among all of the two-media decision rules. Exhibit 6-14 paints a picture similar to the one already shown for dust in Exhibit 6-11. Certain abatements never have positive net benefits (the combination of high-end paint and low-end soil abatements and of low-end paint and high-end soil abatements), one form of abatement always generates positive net benefits (high-end soil), and some abatements generate positive net benefits for some homes and negative net benefits for others (high-end paint,low-end paint, low-end soil, recurrent dust, low-end paint and low-end soil, and nonrecurrent dust). Most notable among the latter are the homes where high-end paint abatement has been induced. The overwhelming majority of these (97%) have negative net benefits.

The biggest difference between the single-medium rule based upon dust and the two-media rule based upon soil and dust is that the two-media rule induces nearly half of a million homes to undertake low-end soil abatement that results in negative net benefits. This difference can be construed as the price to pay for specifying a two-media rather than a single-medium decision rule.

Exhibit 6 - 12

Benefit-Cost Results for Two Media Plus Condition Decision Rules

Decision Rules	Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Benefits ($ million)	Abatement Costs ($ million)	Net Benefits (Exclusive of Testing Costs) ($ million)	Testing Costs ($ million)	Net Benefits (Including Testing Costs) ($ million)	Total Number of Abatements (1000s)	Number of Abatements with Negative Net Benefits (1000s)
2-Media Plus Condition	2,300	1,200	-	Yes	34,920	31,903	3,017	24,346	(21,329)	16,197	7,583
	2,300	-	20	Yes	11,249	28,689	(17,440)	14,982	(32,422)	8,169	7,255
	-	1,200	20	Yes	33,009	29,991	3,017	24,346	(21,329)	15,702	7,215

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Exhibit 6 - 13

Distribution of Abatement Choices for Two Media Plus Condition Decision Rules

Decision Rules	Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Number of Homes Abated by Abatement Type (1000s)										
					HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NR D	Total
2-Media Plus Condition	2,300	1,200	-	Yes	4,186	2,672	74	1,006	276	0	114	18	74	7,777	16,197
	2,300	-	20	Yes	4,220	2,755	0	1,006	0	0	114	0	74	0	8,169
	-	1,200	20	Yes	4,246	2,770	74	411	276	0	114	18	16	7,777	15,702

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Abatement Codes

HP = High Paint Abatement

LP = Low Paint Abatement

HS = High Soil Abatement

LS = Low Soil Abatement

RD = Recurrent Dust Abatement

HP/HS = High Paint, High Soil Abatements

HP/LS = High Paint, Low Soil Abatements

LP/HS = Low Paint, High Soil Abatements

LP/LS = Low Paint, Low Soil Abatements

NR D = Nonrecurrent Dust Abatement

Exhibit 8 -14

Two Media Hazard Levels: Soil - 2300, Dust - 1200

Induced Abatement	Stategy Selected	Total 50-Year Benefits ($ millions)	Total 50-Year Costs ($ millions)	Total 50-Year Net Benefits ($ millions)	Total Number of Abatements (1000's)	Proportion of Abatements	Abatements With Negative Net Benefits (1000's)	Minimum Individual Net Benefits ($)	Maximum Individual Net Benefits ($)	Minimum Soil Level (ppm)	Maximum Soil Level (ppm)	Minimum Dust Level (ppm)	Maximum Dust Level (ppm)	Minimum Interior Paint (mg/cm²)	Maximum Interior Paint (mg/cm²)
No	None	0	0	0	0		0	0	0	0	2,300	0	1,200	0	22
Yes	HP	5,301	20,260	(14,960)	4,186	25.84%	4,053	(9,690)	2,629	0	2,200	0	5,900	1	22
	LP	1,360	3,387	(2,027)	2,672	16.50%	2,469	(2,557)	7,142	0	2,200	0	5,900	1	22
	HS	290	272	18	74	0.46%	0	533	533	1,100	1,100	3,300	3,300	5	5
	LS	3,724	3,475	249	1,006	6.21%	469	(2,228)	8,843	3,000	8,800	1,100	5,800	0	11
	RD	885	978	(92)	276	1.71%	202	(3,526)	1,694	100	1,200	1,400	3,600	6	13
	HP/LS	564	943	(379)	114	0.70%	114	(8,514)	(2,466)	3,100	8,800	1,100	1,200	10	11
	LP/HS	65	87	(22)	18	0.11%	18	(3,901)	(1,689)	1,100	1,200	2,500	3,300	5	11
	LP/LS	260	350	(91)	74	0.46%	58	(4,001)	2,356	3,100	8,800	1,100	1,200	10	11
	NR D	22,472	2,150	20,322	7,777	48.02%	200	(130)	13,126	0	600	1,300	5,900	0	10
Total		34,920	31,903	3,017	16,196		7,583								

Abatement Codes

HP = High Paint Abatement

LP = Low Paint Abatement

HS = High Soil Abatement

LS = Low Soil Abatement

RD = Recurrent Dust Abatement

HP/HS = High Paint, High Soil Abatements

HP/LS = High Paint, Low Soil Abatements

LP/HS = Low Paint, High Soil Abatements

LP/LS = Low Paint, Low Soil Abatements

NR D = Nonrecurrent Dust Abatement

Three-Media Hazard Levels

Exhibit 6-15 shows the benefit-cost results for the combination of three-media hazard levels generating the highest net benefits (soil = 2300 ppm; dust = 1200 ppm; paint = 20 mg/cm^2). Adding one more dimension to the decision rule does not change the optimal hazard levels for soil, paint, or dust observed under the single-medium and two-media decision rules. It does however change the net benefits, lowering them slightly since homeowners have one more constraint on their decisions. The net benefits for the 2300/1200/20 rule are positive ($2.7 billion) but slightly smaller than those of the single-medium and two-media decision rules. Of the 16.3 million abatements induced by these hazard levels, about 47% lead to negative net benefits. The major difference between the abatements induced by this decision rule and those induced by the single-medium and the two-media decision rules is that more high-end paint, more low-end soil, and more low-end paint/low-end soil abatements are conducted.

6.2.3 Other Decision Rules to Consider

Among the set of decision rules that specify hazard levels, a rule based upon a dust hazard level of 1200 ppm and a paint condition criterion generates the highest net benefits ($3.3 billion). It is important to note that, while this decision rule generates the highest net benefits, other soil, dust, and paint hazard levels can generate net benefits of lower but similar magnitude. Exhibit 6-16 shows other top combinations of different hazard levels. They each generate net benefits within $2.2 billion of the highest net benefits achievable under a decision rule based upon dust equal to 1200 ppm. This expanded set of alternatives does not offer hazard levels for dust that are lower nor are there any two-media or three-media decision rules that are more stringent, with one exception. A two-media decision rule based upon a soil hazard level of 2200 ppm and a dust hazard level of 1200 generates net benefits of $1.4 billion.

These and other alternatives may also be contenders for an optimal set of soil and dust hazard levels if factors not yet encompassed in the current analysis are weighed in EPA's decisionmaking. One such possibility is to choose the set of hazard levels that keeps the risk at an individual home of exceeding a blood lead concentration of 15 ug/dl below 5%. This can be achieved with a hazard level of 500 ppm for soil and one of 400 ppm for dust, in addition to the paint condition criterion. As shown in Exhibit 6-17, these hazard levels have a net benefit of minus $18.8 billion.

All of the above decision rules considered so far, including the voluntary optimum, are predicated upon testing homes. With this information, abatement decisions can be based upon the circumstances of the homes, which offers the possibility of finding the best abatement for each home and as a result, increasing the net benefits of abatement. An altogether different approach would be to apply a given type of abatement to all homes, without conducting any prior tests. Clearly, under this approach, some homes would be abated when abatement was not appropriate, resulting in negative net benefits, but this is also the case for all of the decision rules besides the voluntary optimum. The central issue is whether these kinds of errors would be offset by savings in testing costs. The results for the voluntary optimum suggest one means for implementing such an approach in a way that increases overall net benefits.

Exhibit 6 - 15

Three Media Hazard Levels: Soil = 2300, Dust = 1200, Interior Paint = 20

Induced Abatement	Stategy Selected	Total 50-Year Benefits ($ millions)	Total 50-Year Costs ($ millions)	Total 50-Year Net Benefits ($ millions)	Total Number of Abatements (1000's)	Proportion of Abatements	Abatements With Negative Net Benefits (1000's)	Minimum Individual Net Benefits ($)	Maximum Individual Net Benefits ($)	Minimum Soil Level (ppm)	Maximum Soil Level (ppm)	Minimum Dust Level (ppm)	Maximum Dust Level (ppm)	Minimum Interior Paint (mg/cm²)	Maximum Interior Paint (mg/cm²)
No	None	0	0	0	0		0	0	0	0	2,300	0	1,200	0	20
Yes	HP	5,360	20,555	(15,196)	4,246	26.06%	4,114	(9,690)	2,629	0	2,200	0	5,900	1	22
	LP	1,365	3,438	(2,073)	2,712	16.64%	2,508	(2,557)	7,142	0	2,200	0	5,900	1	22
	HS	290	272	18	74	0.45%	0	533	533	1,100	1,100	3,300	3,300	5	5
	LS	3,724	3,475	249	1,006	6.17%	469	(2,228)	8,843	3,000	8,800	1,100	5,800	0	11
	RD	885	978	(92)	276	1.70%	202	(3,526)	1,694	100	1,200	1,400	3,600	6	13
	HP/LS	564	943	(379)	114	0.70%	114	(8,514)	(2,466)	3,100	8,800	1,100	1,200	10	11
	LP/HS	65	87	(22)	18	0.11%	18	(3,801)	(1,689)	1,100	1,200	2,500	3,300	5	11
	LP/LS	260	350	(91)	74	0.46%	58	(4,001)	2,356	3,100	8,800	1,100	1,200	10	11
	NR D	22,472	2,150	20,322	7,777	47.72%	200	(130)	13,126	0	600	1,300	5,900	0	10
Total		34,984	32,248	2,736	16,297		7,683								

Abatement Codes

HP = High Paint Abatement

LP = Low Paint Abatement

HS = High Soil Abatement

LS = Low Soil Abatement

RD = Recurrent Dust Abatement

HP/HS = High Paint, High Soil Abatements

HP/LS = High Paint, Low Soil Abatements

LP/HS = Low Paint, High Soil Abatements

LP/LS = Low Paint, Low Soil Abatements

NR D = Nonrecurrent Dust Abatement

Exhibit 6-16
Near Contenders for Highest Net Benefits

Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Total Benefits ($ millions)	Total Costs ($ millions)	Net Benefits ($ millions)	Total Number of Abatements (1000's)	Abatements With Negative Net Benefits (1000's)
—	1,200	—	32,945	29,646	3,299	15,602	7,114
—	1,200	21	33,009	29,991	3,017	15,702	7,215
—	1,200	20	33,009	29,991	3,017	15,702	7,215
3,000	1,200	—	34,920	31,903	3,017	16,197	7,583
2,900	1,200	—	34,920	31,903	3,017	16,197	7,583
2,800	1,200	—	34,920	31,903	3,017	16,197	7,583
2,700	1,200	—	34,920	31,903	3,017	16,197	7,583
2,600	1,200	—	34,920	31,903	3,017	16,197	7,583
2,500	1,200	—	34,920	31,903	3,017	16,197	7,583
2,400	1,200	—	34,920	31,903	3,017	16,197	7,583
2,300	1,200	—	34,920	31,903	3,017	16,197	7,583
3,000	1,200	21	34,984	32,248	2,736	16,297	7,684
3,000	1,200	20	34,984	32,248	2,736	16,297	7,684
2,900	1,200	21	34,984	32,248	2,736	16,297	7,684
2,900	1,200	20	34,984	32,248	2,736	16,297	7,684
2,800	1,200	21	34,984	32,248	2,736	16,297	7,684
2,800	1,200	20	34,984	32,248	2,736	16,297	7,684
2,700	1,200	21	34,984	32,248	2,736	16,297	7,684
2,700	1,200	20	34,984	32,248	2,736	16,297	7,684
2,600	1,200	21	34,984	32,248	2,736	16,297	7,684
2,600	1,200	20	34,984	32,248	2,736	16,297	7,684
2,500	1,200	21	34,984	32,248	2,736	16,297	7,684
2,500	1,200	20	34,984	32,248	2,736	16,297	7,684
2,400	1,200	21	34,984	32,248	2,736	16,297	7,684
2,400	1,200	20	34,984	32,248	2,736	16,297	7,684
2,300	1,200	21	34,984	32,248	2,736	16,297	7,684
2,300	1,200	20	34,984	32,248	2,736	16,297	7,684
—	1,300	—	31,413	29,128	2,285	14,654	7,031
—	1,400	—	29,669	27,557	2,112	13,954	6,803
—	1,300	21	31,477	29,473	2,004	14,754	7,132
—	1,300	20	31,477	29,473	2,004	14,754	7,132
3,000	1,300	—	33,389	31,385	2,004	15,249	7,500
2,900	1,300	—	33,389	31,385	2,004	15,249	7,500
2,800	1,300	—	33,389	31,385	2,004	15,249	7,500
2,700	1,300	—	33,389	31,385	2,004	15,249	7,500
2,600	1,300	—	33,389	31,385	2,004	15,249	7,500
2,500	1,300	—	33,389	31,385	2,004	15,249	7,500
2,400	1,300	—	33,389	31,385	2,004	15,249	7,500
2,300	1,300	—	33,389	31,385	2,004	15,249	7,500
2,900	1,400	—	32,847	30,917	1,929	14,869	7,272
2,800	1,400	—	32,847	30,917	1,929	14,869	7,272
2,700	1,400	—	32,847	30,917	1,929	14,869	7,272

Exhibit 6-16
Near Contenders for Highest Net Benefits

Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Total Benefits ($ millions)	Total Costs ($ millions)	Net Benefits ($ millions)	Total Number of Abatements (1000's)	Abatements With Negative Net Benefits (1000's)
2,600	1,400	—	32,847	30,917	1,929	14,869	7,272
2,500	1,400	—	32,847	30,917	1,929	14,869	7,272
2,400	1,400	—	32,847	30,917	1,929	14,869	7,272
2,300	1,400	—	32,847	30,917	1,929	14,869	7,272
—	1,400	21	29,732	27,902	1,831	14,055	6,903
—	1,400	20	29,732	27,902	1,831	14,055	6,903
3,000	1,400	—	31,644	29,813	1,831	14,549	7,272
3,000	1,300	21	33,453	31,730	1,722	15,349	7,601
3,000	1,300	20	33,453	31,730	1,722	15,349	7,601
2,900	1,300	21	33,453	31,730	1,722	15,349	7,601
2,900	1,300	20	33,453	31,730	1,722	15,349	7,601
2,800	1,300	21	33,453	31,730	1,722	15,349	7,601
2,800	1,300	20	33,453	31,730	1,722	15,349	7,601
2,700	1,300	21	33,453	31,730	1,722	15,349	7,601
2,700	1,300	20	33,453	31,730	1,722	15,349	7,601
2,600	1,300	21	33,453	31,730	1,722	15,349	7,601
2,600	1,300	20	33,453	31,730	1,722	15,349	7,601
2,500	1,300	21	33,453	31,730	1,722	15,349	7,601
2,500	1,300	20	33,453	31,730	1,722	15,349	7,601
2,400	1,300	21	33,453	31,730	1,722	15,349	7,601
2,400	1,300	20	33,453	31,730	1,722	15,349	7,601
2,300	1,300	21	33,453	31,730	1,722	15,349	7,601
2,300	1,300	20	33,453	31,730	1,722	15,349	7,601
2,900	1,400	21	32,910	31,262	1,648	14,969	7,372
2,900	1,400	20	32,910	31,262	1,648	14,969	7,372
2,800	1,400	21	32,910	31,262	1,648	14,969	7,372
2,800	1,400	20	32,910	31,262	1,648	14,969	7,372
2,700	1,400	21	32,910	31,262	1,648	14,969	7,372
2,700	1,400	20	32,910	31,262	1,648	14,969	7,372
2,600	1,400	21	32,910	31,262	1,648	14,969	7,372
2,600	1,400	20	32,910	31,262	1,648	14,969	7,372
2,500	1,400	21	32,910	31,262	1,648	14,969	7,372
2,500	1,400	20	32,910	31,262	1,648	14,969	7,372
2,400	1,400	21	32,910	31,262	1,648	14,969	7,372
2,400	1,400	20	32,910	31,262	1,648	14,969	7,372
2,300	1,400	21	32,910	31,262	1,648	14,969	7,372
2,300	1,400	20	32,910	31,262	1,648	14,969	7,372
—	1,500	—	28,846	27,292	1,554	13,564	6,762
3,000	1,400	21	31,708	30,158	1,549	14,650	7,372
3,000	1,400	20	31,708	30,158	1,549	14,650	7,372
2,900	1,500	—	32,024	30,652	1,372	14,479	7,231
2,800	1,500	—	32,024	30,652	1,372	14,479	7,231

Exhibit 6-16
Near Contenders for Highest Net Benefits

Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Total Benefits ($ millions)	Total Costs ($ millions)	Net Benefits ($ millions)	Total Number of Abatements (1000's)	Abatements With Negative Net Benefits (1000's)
2,700	1,500	—	32,024	30,652	1,372	14,479	7,231
2,600	1,500	—	32,024	30,652	1,372	14,479	7,231
2,500	1,500	—	32,024	30,652	1,372	14,479	7,231
2,400	1,500	—	32,024	30,652	1,372	14,479	7,231
2,300	1,500	—	32,024	30,652	1,372	14,479	7,231
2,200	1,200	—	38,380	37,029	1,350	18,267	9,653
—	1,500	21	28,910	27,637	1,273	13,665	6,862
—	1,500	20	28,910	27,637	1,273	13,665	6,862
3,000	1,500	—	30,821	29,548	1,273	14,159	7,231
—	1,600	—	28,342	27,218	1,124	13,351	6,762
2,800	1,500	21	32,088	30,997	1,090	14,579	7,331
2,800	1,500	20	32,088	30,997	1,090	14,579	7,331
2,700	1,500	21	32,088	30,997	1,090	14,579	7,331
2,700	1,500	20	32,088	30,997	1,090	14,579	7,331
2,600	1,500	21	32,088	30,997	1,090	14,579	7,331
2,600	1,500	20	32,088	30,997	1,090	14,579	7,331
2,500	1,500	21	32,088	30,997	1,090	14,579	7,331
2,500	1,500	20	32,088	30,997	1,090	14,579	7,331
2,400	1,500	21	32,088	30,997	1,090	14,579	7,331
2,400	1,500	20	32,088	30,997	1,090	14,579	7,331
2,300	1,500	21	32,088	30,997	1,090	14,579	7,331
2,300	1,500	20	32,088	30,997	1,090	14,579	7,331

Exhibit 6-17
Alternative Hazard Levels Based Upon Soil = 500, Dust = 400

Soil (ppm)	Dust (ppm)	Paint (XRF)	Total Benefits ($ millions)	Total Costs ($ millions)	Net Benefits ($ millions)	Total Number of Abatements (1000's)	Abatements With Negative Net Benefits (1000's)
500	400	—	66,688	85,445	(18,757)	45,563	21,584
500	400	21	66,752	85,790	(19,038)	45,664	21,685
500	400	20	66,752	85,790	(19,038)	45,664	21,685
500	400	19	66,711	86,910	(20,199)	45,728	21,749
500	400	18	66,711	86,910	(20,199)	45,728	21,749
500	400	17	66,711	86,910	(20,199)	45,728	21,749
500	400	16	66,711	86,910	(20,199)	45,728	21,749
500	400	15	66,711	86,910	(20,199)	45,728	21,749
500	400	14	66,711	86,910	(20,199)	45,728	21,749
500	400	13	66,711	86,910	(20,199)	45,728	21,749
500	400	12	66,737	86,998	(20,261)	45,728	21,749
500	400	11	66,770	87,229	(20,460)	45,728	21,749
500	400	10	66,770	87,229	(20,460)	45,728	21,749
500	400	9	66,816	87,481	(20,665)	45,728	21,749
500	400	8	67,228	88,478	(21,250)	45,728	21,749
500	400	7	67,438	89,138	(21,699)	45,797	21,818
500	400	6	67,573	90,248	(22,675)	46,049	22,070
500	400	5	67,537	91,457	(23,920)	46,049	22,070
500	400	4	67,623	91,703	(24,079)	46,049	22,191
500	400	3	67,705	92,577	(24,871)	46,304	22,446
500	400	2	68,186	96,479	(28,293)	47,099	23,241
500	400	1	68,993	105,526	(36,533)	49,537	25,679
500	400	0	73,234	146,212	(72,978)	59,039	36,283

Most of the abatements chosen under the voluntary optimum are nonrecurrent dust abatements (99%) (Exhibit 6-2). Since the voluntary optimum decision rule presumes testing prior to the abatement choice, this new approach must impose additional abatements costing no more than the avoided testing costs ($24 billion) to improve on the overall net benefits of the voluntary optimum rule. Given average discounted nonrecurrent dust abatement costs of $267 and the finding that 62.2 million homeowners chose not to abate under the voluntary optimum, the incremental cost of imposing nonrecurrent dust abatement on all homes is $16.6 billion. Some of these homes would also accrue benefits (even though net benefits are negative). There would also be a small loss in benefits from those achieved under the voluntary optimum since the homes choosing low-end paint and low-end soil abatements are not given the choice under this rule. A preliminary estimate suggests a net increase in benefits of about $2 billion.

Adding this estimate to the net costs avoided (equal to $24.2 billion in testing costs avoided minus $16.6 billion in additional abatement costs), there is a net gain of $9.6 billion. In other words, with testing costs, the voluntary optimum decision rule generates net benefits of $10 billion while this hybrid rule, based strictly upon nonrecurrent dust abatement, would generate net benefits of approximately $20 billion. These higher net benefits can be achieved through this uniform approach even though the percentage of homes with negative net benefits (58%) is higher than that of the voluntary optimum (0%) or those of the best of the other decision rules (about 47%).

It is unclear, however, how reliable this particular abatement approach based upon nonrecurrent dust abatement is since it relies exclusively on one, substantial cleaning of every home involved. Nonetheless, the improvements this approach offers underscores the important role that testing costs may play in the abatement choices initiated by hazard levels set under Section 403. It also suggests that there may be ways to construct guidance to the public which takes testing costs into account.

In sum, further investigation of factors not fully considered in this analysis may reveal additional opportunities for creating decision rules to address outstanding EPA concerns, and possibly, to create higher net benefits.

6.3 SUMMARY AND CONCLUSION

Exhibits 6-18 and 6-19 summarize the benefit-cost information presented above for all five sets of decision rules. The final comparison of these results integrates information on the testing costs necessary to implement each of these decision rules. This information was presented in the discussion of the overall net benefits of the voluntary optimum decision rule but not for the other decision rules. Since there is variation in the tests that are required for different decision rules (testing soil or dust for lead content or testing paint for condition or lead content), the testing costs that are prerequisite to abatement decisions also vary.

The inclusion of testing costs does not alter the ranking of nine decision rules considered here. The voluntary optimum still has the highest net benefits ($10 billion). All subsequent decision rules have negative net benefits. The top four among these are based upon a single medium (dust=1200), two media (soil=2300/dust=1200, dust=1200/paint=20), and three media (soil=2300/dust=1200/ paint=20). The overall net benefits of any of these decision rules is approximately minus $21 billion. The three lowest-ranking decision rules all have in common that they are based in some way upon a paint hazard level. The qualitative hazard level based upon paint condition criterion ranks seventh, the two-media rule based upon soil and paint ranks eighth, and the single-medium hazard level based upon paint alone ranks ninth. These outcomes and the finding of significant negative net benefits associated with paint abatement highlight the potentially significant influence of the assumptions made regarding the effectiveness and cost of paint abatement.

Another notable difference between the top-ranked decision rule and the next four is the number of homes abated. The decision rules based upon qualitative or quantitative hazard levels induce no more than 16.3 million abatements, of which 7 to 8 million have negative net benefits. The voluntary optimum leads to nearly three times as many abatements - more than 45 million abatements. None entails negative net benefits. This finding raises the possibility that better decision rules could be created that are both implementable, which is the advantage of the decision rules based upon hazard levels, and that lead to positive and substantial net benefits, which the voluntary optimum does. Since the information bases assumed for the first group and for the voluntary optimum differ substantially, it appears that creating a better means for conveying useful information to guide homeowners' abatement decisions could be a productive route for improving upon the decision rules investigated here. This may be an important point of departure for subsequent investigations.

A more immediate point of departure for investigation is to put the current analysis into perspective by considering the sensitivity of the results to various critical assumptions. Some conclusions from this analysis have been strongly influenced by certain parameters used in the current analysis. For example, the influence of assumptions regarding the cost and extent of abatement of non-intact paint on net benefits has been highlighted. Alternative assumptions about these unit costs and those of other abatements could affect the net benefits and the number of abatements for each decision rule. The discount rate applied to benefits and costs also appears to be particularly influential. The sensitivity of the benefits and costs of different decision rules to these and other parameters is investigated in the next chapter.

Exhibit 6 - 18

Benefit-Cost Results for Five Alternative Decision Rules

Decision Rules			Soil (ppm)	Dust (ppm)	Paint mg/cm²	Nonintact Paint Abatement Recommended	Benefits ($ million)	Abatement Costs ($ million)	Net Benefits (Exclusive of Testing Costs) ($ million)	Testing Costs ($ million)	Net Benefits (Including Testing Costs) ($ million)	Total Number of Abatements (1000s)	Number of Abatements with Negative Net Benefits (1000s)
1.	Voluntary Optimum		-	-	-	No	48,190	13,896	34,294	24,222	10,072	45,165	0
2.	Paint Condition Only		-	-	-	Yes	7,319	24,668	(17,349)	14,987	(32,336)	7,063	6,685
3.	Single Medium Plus Condition	3a.	2,300	-	-	Yes	11,186	28,345	(17,159)	24,222	(41,381)	8,069	7,154
		3b.	-	1,200	-	Yes	32,945	29,646	3,299	24,227	(20,928)	15,602	7,114
		3c.	-	-	20	Yes	7,383	25,014	(17,631)	14,906	(32,537)	7,164	6,786
4.	2-Media Plus Condition	4a.	2,300	1,200	-	Yes	34,920	31,903	3,017	24,227	(21,210)	16,197	7,583
		4b.	2,300	-	20	Yes	11,249	28,689	(17,440)	24,222	(41,662)	8,170	7,255
		4c.	-	1,200	20	Yes	33,009	29,992	3,017	24,227	(21,210)	15,702	7,215
5.	3-Media Plus Condition		2,300	1,200	20	Yes	34,984	32,248	2,736	24,231	(21,495)	16,297	7,684

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of XRF level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefit.

Exhibit 6 - 19

Distribution of Abatement Choices for Five Alternative Decision Rules

Decision Rules			Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Number of Homes Abated by Abatement Type (1000s)										
							HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NR D	Total
1.	Voluntary Optimum					No	0	21	0	577	0	0	0	0	0	44,567	45,165
2.	Paint Condition Only		-	-	-	Yes	4,160	2,774	0	0	0	0	114	0	16	0	7,063
3.	Single Medium Plus Condition	3a.	2,300	-	-	Yes	4,160	2,716	0	1,006	0	0	114	0	74	0	8,069
		3b.	-	1,200	-	Yes	4,186	2,731	74	411	276	0	114	18	16	7,777	15,602
		3c.	-	-	20	Yes	4,221	2,814	0	0	0	0	114	0	16	0	7,164
4.	2-Media Plus Condition	4a.	2,300	1,200	-	Yes	4,186	2,672	74	1,006	276	0	114	18	74	7,777	16,197
		4b.	2,300	-	20	Yes	4,221	2,756	0	1,006	0	0	114	0	74	0	8,170
		4c.	-	1,200	20	Yes	4,247	2,770	74	411	276	0	114	18	16	7,777	15,702
5.	3-Media Plus Condition		2,300	1,200	20	Yes	4,247	2,712	74	1,006	276	0	114	18	74	7,777	16,297

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Abatement Codes

HP = High Paint Abatement
LP = Low Paint Abatement
HS = High Soil Abatement
LS = Low Soil Abatement
RD = Recurrent Dust Abatement
HP/HS = High Paint, High Soil Abatements
HP/LS = High Paint, Low Soil Abatements
LP/HS = Low Paint, High Soil Abatements
LP/LS = Low Paint, Low Soil Abatements
NR D = Nonrecurrent Dust Abatement

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of XRF level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

7. SENSITIVITY ANALYSES

Any modelling to support environmental policy analysis depends on making judgments in how to depict human behavior, environmental circumstances, and their interactions. These judgments draw variously on the analysts' expertise, existing knowledge about the problem at hand, the advice of relevant specialists, and conclusions drawn from available data and studies. One objective in combining insights gleaned from these sources is to fill the substantial gaps in current understanding in a way that provides a "reasonable" characterization of the problem at hand. Still, what constitutes a reasonable characterization may not be the definitive characterization. It may apply to a large number but not all circumstances in the real world. Or, it could be based on a set of assumptions about which even the best-informed analysts would disagree. More than likely, it will be subject to both conditions.

This chapter considers the influence of alternative assumptions on the benefits and cost of lead abatement in residential settings. The results are presented as sensitivity analyses because they represent alternative specifications to the model used to calculate benefits and costs rather than radical reconfigurations of the modelling framework. The aim is to determine whether changing a relatively small number of parameters but in a credible way can lead to substantial changes in the policy-relevant outcomes.

The number of parameters considered in this chapter is limited to a few selected items. In part, this selection is due to model refinement which has already taken place. Yesterday's "sensitivity analyses" became today's model enhancements, which were formally incorporated into the framework. The selection also stems from the desire to focus on parameters that had a significant likelihood of influencing the policy-relevant outcomes. By no means are the parameters examined here the ones with the greatest potential for changing these outcomes. Other modelling assumptions have greater potential but they often represent more controversial assumptions. Finally, the selection derives from a limit on the number of sensitivity analyses that can be generated. The binding constraint is not so much a limit on the number of modelling iterations that can be run since with faster computing power, immense numbers of modelling runs can be undertaken with changes in assumptions engineered from one iteration to the next. The real limit is on the ability to organize the results from a large number of iterations in a way that lends itself to reliable quality assurance, interpretation, and presentation.

In the next section, a brief overview of potential sensitivity analyses is provided. In the three subsequent sections, sensitivity analyses based upon alternative cost and discounting assumptions are presented.

7.1 POTENTIAL SENSITIVITY ANALYSES

Two sets of parameters will be discussed. The first set includes parameters tied primarily to cost calculations and the second, ones that are relevant to benefit calculations. This classification masks what may be the ultimate factor determining whether they should be evaluated. It is the effect of changing these parameters on the optimal hazard levels of different decision rules and the net benefits of these different decision rules which is one of the most policy-relevant outcomes that can come from any sensitivity analyses. However, presenting the sensitivity analyses in this manner may give clearer indications on where these assumptions fit into the model.

For the cost calculations, two general sets of assumptions stand out as candidates for sensitivity analyses. The first set encompasses assumptions regarding the unit costs of abatement of soil, dust, or paint. For soil abatement, possible variations include different assumptions regarding the nature of abatement, the level at which soil is considered hazardous, and the costs of transportation and disposal. For dust abatement, unit costs currently depend on the type and frequency of different levels of abatement. For paint abatement, costs are highly dependent on the condition and amount of lead paint present, among other factors. Some of these variations may be captured explicitly or implicitly in the range of unit cost estimates. The results in previous chapters were based upon a set of "medium" cost estimates. This chapter considers the impacts that using low and high unit cost estimates have on the benefits and costs of different decision rules and their optimal hazard levels. The second set of assumptions relates to assumptions about testing costs. The numbers of soil, dust, and paint samples and the numbers of households tested are critical components of the unit and aggregate costs, respectively. Furthermore, the costs per sample could have considerable regional variation.

The benefit calculations depend on a wide array of assumptions that could be subjected to sensitivity analyses. Because there are so many potentially influential assumptions, it is important to narrow the set of potential candidates. Determining which assumptions are the best candidates for sensitivity analysis and how the given assumptions should be altered complicates the task of conducting the sensitivity analysis. For example, the effectiveness and durability of various forms of abatement have not been thoroughly quantified by studies to date but for the purposes of calculating benefits it is necessary to quantify them explicitly. It is possible that there are alternate, credible assumptions besides those currently made in this analysis that would alter the policy-relevant outcomes.

Some of the possible variations in assumptions are substantial enough to constitute major model revisions rather than sensitivity analyses. For example, the main analysis did not include benefits for children who already exist at the beginning of the time period covered by the model. Although benefits for these children can be estimated, incorporating the influence of these benefits on abatements decisions is more difficult and will require a significant adjustment to the model. The potential benefits to adults from avoided high blood pressure effects from exposure to lead have not been included in the model either. If exposures for adults to lead contamination from residential soil, dust, or paint are significant, these benefits could have a substantial impact on policy-relevant outcomes of the analysis, including the timing, number, and types of abatements and most important, the optimal hazard levels for different decision rules. Like the benefits for existing children, changing the model to make abatement decisions responsive to adult exposures will require a significant adjustments since abatement will no longer be exclusively induced by births. A further obstacle to incorporating such benefits is that the evidence supporting their validity is very limited.

Questions have also been raised about the variation in benefits that derives from differences in exposures from lead contamination in bare versus covered soil. Exposure to the former entails higher ingestion of lead than exposure to the latter, under otherwise similar circumstances, which means that bare soil could have a lower optimal hazard level than covered soil. The magnitude of these differences is unknown and little information is available to suggest a conclusive resolution of this issue. Dealing with a related set of assumptions - soil and dust ingestion rates employed in the IEUBK model - offers another target for sensitivity analyses but setting a new range for these values to address the bare/covered soil issue is almost an ad hoc exercise.

Because of the breadth of the potential changes implicit in varying these assumptions, to date a conservative approach has been taken toward what will be presented here. As mentioned above, the first sensitivity analysis considers low and high unit cost estimates. The second sensitivity analysis focuses on changing one particular parameter of the analysis that has a large potential for affecting policy-relevant outcomes but is also relatively easy to implement. This parameter is the discount rate used to express the monetary value of future benefits and costs in contemporary terms. A rate of 7% was used for the analysis presented in previous chapters. An alternate approach, which has been used by the Agency in some other regulatory analyses, involves a two-stage discounting procedure that employs both 3% and 7%. Results using this procedure will be presented below. The third sensitivity analysis illustrates the kinds of effects that the potential benefits to adults and existing children could have on the benefit-cost analysis. For this exercise, the benefits estimated for newborn children were supplemented by estimates for adults and existing children but the basis for abatement decisions - the imminent birth of a child - remains the same.

7.2 ALTERNATIVE COST ASSUMPTIONS

The information on unit costs of abatement provided in Chapter 4 provides the basis for a wide array of different cost assumptions. For the abatement of one single medium, three different estimates were developed - a high one, a low one, and a medium one. Once the abatement of more than one medium is considered, the number of alternative cost combinations that could apply to a given home grows exponentially. With the addition of one more medium to abate, the number of cost estimates increases from three to nine. With the addition of a third medium, the number of cost estimates rises to twenty-seven. If information on the likely frequency of these different cost combinations were available, these different cost combinations could be integrated explicitly in the abatement decisions of the homeowners, such as by having homeowners consider the expected costs of high-end paint and low-end soil abatement, rather than only the medium estimates. However, information on the distributions of abatement costs was considered too limited to allow approximating such distributions reliably.

One alternative to trying to chararacterize the distributions of cost estimates in their entirety is to look at the impact that the extreme values have on the policy-relevant outcomes. On this basis, at least it would be feasible to establish boundaries on the possible benefit-cost results and the estimated optimal hazard levels. While the low and high unit cost estimates presented in Chapter 4 are not the ultimate minimum and maximum values, they were constructed to be representative of the lower and upper ranges of values observed in practice. As such, the low and high unit values of Chapter 4 are probably appropriate for testing the boundaries of the benefit-cost analysis.

The sensitivity analyses for the high and low cost scenarios focuses on comparisons of the five alternative decision rules targeted in Chapter 6. To facilitate these comparisons, tables were constructed for each scenario analogous to the ones presenting the benefit-cost results and the distribution of abatement choices in Chapter 6 (Exhibits 6-18 and 6-19). Exhibits 7-1 and 7-2 present these findings for the high cost scenario. Exhibits 7-3 and 7-4 present those for the low cost scenario.

For the high cost scenario, the most important finding may be that the optimal hazard levels are exactly the same for most versions of the decision rules. As shown in Exhibit 7-1, for dust the optimal hazard level is still 1,200 ppm in all cases (single medium, two-media, three-media). Furthermore, the decision rules with the highest net benefits are still those which involve setting a dust hazard level. For paint the optimal level is still 20 mg/cm^2. For soil, the optimal hazard level is still 2,300 ppm in the decision rules having the highest net benefits (three media, two media when combined with a dust hazard level) but is 3,000 ppm for decision rules which have markedly lower net benefits. In all decision rules except the voluntary optimum, the net benefits are negative. The net benefits for the voluntary optimum decline by 18% but the number of abatements declines more dramatically, by 27%, as shown in Exhibit 7-2. The numbers of abatements induced by the other decision rules stay basically the same. There are minor shifts away from the more expensive abatements, such as high-end paint/low-end soil, but mainly the distributions of abatements change little if at all.

For the low cost scenario, the optimal levels for dust and paint again remain at the levels generated by the main analysis (1,200 ppm for dust and 20 mg/cm^2 for paint) but the optimal hazard level for soil is 35% lower. As shown in Exhibit 7-3, the optimal hazard level for soil in all relevant decision rules is 1,500 ppm. This appears to be the most significant difference in the results for the induced rules. Although the net benefits are substantially larger for all decision rules and positive (exclusive of testing costs) for most, the net benefits are still negative for the decision rules that had negative net benefits in the main analysis (the paint condition rule, the single medium soil and paint decision rules and the two-media rule combining soil and paint). Notably the number of abatements having negative net benefits does not decline appreciably. In the case of the single-medium dust rule, for example, the decline is only 10%.

The other significant differences between the results for the main analysis and this sensitivity analysis are associated with the voluntary optimum. As shown in Exhibit 7-4, the number of abatements jumps from 45 million to almost 78 million. As before, an overwhelming majority of these are nonrecurrent dust abatements (95%). There is however a slight adjustment to the distribution with the addition of high-end soil abatements, when there had been none before, and with a six-fold increase in the number of low-end soil and low-end paint abatements.

In conclusion, this bounding exercise indicates that findings regarding optimal dust and paint hazard levels may not be affected by a better representation of the distribution of abatement costs. Dramatic upward and downward revisions applied simultaneously to all abatements did not change the optimal hazard levels for dust and paint. This does not however categorically rule out revisions in cost estimates which could affect the optimal dust and paint hazard levels. It is important to remember that the abatement choices are the result of comparing all abatement choices allowed by a given rule. If cost estimates for abatements to one medium in particular are significantly revised without changes to the estimated abatement costs for other media, the optimal hazard level for that medium is likely to change. Whether this is a rare possibility or not is unknown. Given current information it seems unlikely to occur with the estimated dust abatement costs, given their significantly lower magnitudes, but it could affect the estimated paint abatement costs, which already exhibit a very broad range.

This sensitivity analysis has shown that the optimal soil hazard level could be susceptible to changes in assumptions regarding the costs of abatement. While the optimal soil hazard level held constant at 2,300 ppm for an upward revision in all abatement costs, it fell to 1,500 ppm when all costs were lowered. Although it has already been shown in Chapter 6 that certain small changes in the hazard level for a particular medium do not change net benefits significantly, in this case there is a significant change. In the main analysis, the best decision rule, given that the soil hazard level is fixed at 1,500 ppm, has negative net benefits (-$7 billion).[1] When the soil hazard level is instead allowed to fluctuate, the best decision rule involving soil is one having a soil hazard level of 2,300 ppm. This rule has positive net benefits ($3 billion). Consequently, it appears that the evidence for setting a single hazard level for soil is not clearcut. Instead, a range from 1,500 to 2,300 ppm is supported by the model when bounding cost assumptions are applied.

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1 The best decision rule when the soil hazard level is fixed at 1,500 ppm and the paint condition applies is a two-media rule where the dust hazard level is 1,200 ppm.

Exhibit 7-1

Benefit-Cost Results for Five Alternative Decision Rules, High Cost Scenario

Decision Rules			Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Benefits ($ million)	Abatement Costs ($ million)	Net Benefits (Exclusive of Testing Costs) ($ million)	Total Number of Abatements (1000s)	Number of Abatements with Negative Net Benefits (1000s)
1.	Voluntary Optimum		-	-	-	No	43,122	15,008	28,114	33,098	0
2.	Paint Condition Only		-	-	-	Yes	6,991	30,135	(23,144)	7,063	6,726
3.	Single Medium Plus Condition	3a.	3,000	-	-	Yes	9,983	34,239	(24,256)	7,750	7,195
		3b.	-	1,200	-	Yes	32,604	37,166	(4,562)	15,602	7,548
		3c.	-	-	20	Yes	7,055	30,562	(23,507)	7,164	6,827
4.	2-Media Plus Condition	4a.	2,300	1,200	-	Yes	34,907	40,820	(5,913)	16,197	8,017
		4b.	3,000	-	20	Yes	10,047	34,666	(24,619)	7,850	7,295
		4c.	-	1,200	20	Yes	32,668	37,592	(4,925)	15,702	7,649
5.	3-Media Plus Condition		2,300	1,200	20	Yes	34,970	41,246	(6,276)	16,297	8,118

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of XRF level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit 7-2

Distribution of Abatement Choices for Five Alternative Decision Rules, High Cost Scenario

Decision Rules			Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Number of Homes Abated by Abatement Type (1000s)										
							HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NR D	Total
1.	Voluntary Optimum					No	0	0	0	257	0	0	0	0	0	32,840	33,098
2.	Paint Condition Only		-	-	-	Yes	4,249	2,774	0	0	0	0	24	0	16	0	7,063
3.	Single Medium Plus Condition	3a.	3,000	-	-	Yes	4,160	2,716	0	686	0	0	114	0	74	0	7,750
		3b.	-	1,200	-	Yes	4,275	2,731	0	411	350	0	24	18	16	7,777	15,602
		3c.	-	-	20	Yes	4,310	2,814	0	0	0	0	24	0	16	0	7,164
4.	2-Media Plus Condition	4a.	2,300	1,200	-	Yes	4,186	2,672	0	1,008	350	0	114	18	74	7,777	16,197
		4b.	3,000	-	20	Yes	4,221	2,756	0	686	0	0	114	0	74	0	7,850
		4c.	-	1,200	20	Yes	4,336	2,770	0	411	350	0	24	18	16	7,777	15,702
5.	3-Media Plus Condition		2,300	1,200	20	Yes	4,247	2,712	0	1,008	350	0	114	18	74	7,777	16,297

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Abatement Codes

HP = High Paint Abatement
LP = Low Paint Abatement
HS = High Soil Abatement
LS = Low Soil Abatement
RD = Recurrent Dust Abatement

HP/HS = High Paint, High Soil Abatements
HP/LS = High Paint, Low Soil Abatements
LP/HS = Low Paint, High Soil Abatements
LP/LS = Low Paint, Low Soil Abatements
NR D = Nonrecurrent Dust Abatement

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of XRF level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit 7-3

Benefit-Cost Results for Five Alternative Decision Rules, Low Cost Scenario

Decision Rules			Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Benefits ($ million)	Abatement Costs ($ million)	Net Benefits (Exclusive of Testing Costs) ($ million)	Total Number of Abatements	Number of Abatements with Negative Net Benefits (1000s)
1.	Voluntary Optimum		-	-	-	No	58,703	13,950	44,753	77,738	0
2.	Paint Condition Only		-	-	-	Yes	7,566	18,972	(11,405)	7,063	6,328
3.	Single Medium Plus Condition	3a.	1,500	-	-	Yes	15,647	24,778	(9,130)	10,649	6,394
		3b.	-	1,200	-	Yes	33,193	21,836	11,357	15,602	6,463
		3c.	-	-	20	Yes	7,630	19,235	(11,605)	7,164	6,429
4.	2-Media Plus Condition	4a.	1,500	1,200	-	Yes	39,382	26,824	12,558	18,776	6,529
		4b.	1,500	-	20	Yes	15,711	25,041	(9,330)	10,750	6,494
		4c.	-	1,200	20	Yes	33,256	22,099	11,157	15,702	6,564
5.	3-Media Plus Condition		1,500	1,200	20	Yes	39,446	27,087	12,359	18,877	6,629

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of XRF level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit 7-4

Distribution of Abatement Choices for Five Alternative Decision Rules, Low Cost Scenario

Decision Rules			Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Number of Homes Abated by Abatement Type (1000s)										
							HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NR D	Total
1.	Voluntary Optimum					No	0	131	163	3,545	0	0	0	0	0	73,899	77,738
2.	Paint Condition Only		-	-	-	Yes	4,120	2,716	0	0	0	27	126	0	74	0	7,063
3.	Single Medium Plus Condition	3a.	1,500	-	-	Yes	4,120	2,708	163	3,423	0	27	126	0	82	0	10,649
		3b.	-	1,200	-	Yes	4,146	2,672	74	411	276	27	126	18	74	7,777	15,602
		3c.	-	-	20	Yes	4,181	2,756	0	0	0	27	126	0	74	0	7,164
4.	2-Media Plus Condition	4a.	1,500	1,200	-	Yes	4,146	2,664	237	3,423	276	27	126	18	82	7,777	18,776
		4b.	1,500	-	20	Yes	4,181	2,747	163	3,423	0	27	126	0	82	0	10,750
		4c.	-	1,200	20	Yes	4,207	2,712	74	411	276	27	126	18	74	7,777	15,702
5.	3-Media Plus Condition		1,500	1,200	20	Yes	4,207	2,704	237	3,423	276	27	126	18	82	7,777	18,877

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Abatement Codes

HP = High Paint Abatement
LP = Low Paint Abatement
HS = High Soil Abatement
LS = Low Soil Abatement
RD = Recurrent Dust Abatement

HP/HS = High Paint, High Soil Abatements
HP/LS = High Paint, Low Soil Abatements
LP/HS = Low Paint, High Soil Abatements
LP/LS = Low Paint, Low Soil Abatements
NR D = Nonrecurrent Dust Abatement

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of XRF level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maxdmizes net benefits.

7.3 ALTERNATIVE DISCOUNTING PROCEDURE

The selection of a discount rate is one of the most debated features of benefit-cost analyses of environmental policies. Part of the concern driving the debate stems from a common feature of environmental policy, which is that costs tend to be incurred in the present or near-term while benefits accrue mostly in the future and sometimes in the distant future. Because of the exponential nature of discounting, an increase in the discount rate leads to a greater than proportional reduction in future benefits (and costs to the extent there are any) and therefore, so the debate goes, discounting biases benefit-cost analysis against environmental regulations. The debate also has a theoretical dimension to it. As Pearce et al. point out, there are two reasons for discounting, which do not necessarily lead to the same rate (Pearce et al., 1989). One reason is to reflect the social rate of time preference. The other reason is to reflect the social opportunity cost of capital. Either a choice must be made between using one or the other, or, some method of combining the two must be employed.

In the main analysis, a single discount rate of 7% was applied to both benefits and costs, as specified in recent guidance from the Office of Management and Budget. As an alternative, a two-stage discounting procedure is considered in this sensitivity analysis. This procedure uses the approach of combining the time and capital elements to discounting cited above and was issued as supplemental guidelines for regulatory impact analysis by EPA in 1989 (Scheraga, 1989). The first step of the procedure calls for annualizing capitalize costs using the marginal rate of return on private investment and adding any operation and maintenance costs to the annualized figures. A rate of 7% and periods of 10, 20, 30, 40, and 50 years for amortizing (annualizing) the capital cost were used in this application. The second step entails discounting both the benefit and cost streams using the consumption rate of interest. As recommended in the guidelines, a rate of 3% was used. The two-stage procedure is appropriate under certain circumstances. The costs of abatement have to be passed on to consumers, since displaced consumption is the means for expressing the opportunity cost of the abatement. That is the case for owner-occupants undertaking lead abatement, since they are also the consumers in question, and is a strong possibility for renters but is dependent on market conditions.

Using the two-stage discounting procedure produces a substantial shift in the magnitude of the estimated benefits and costs of abatement, resulting in much larger net benefits.[2] (See Appendix 7-A for abatement scenario unit costs using the two-stage discounting procedure.) The best single indicator of the greater net benefits is that many of the estimated optimal hazard levels for dust and soil are much more stringent than those estimated in the main analysis. Exhibit 7-5 summarizes the range of optimal hazard levels estimated using different amortization periods in the two-stage procedure.

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2 This outcome derives in part from the performance of the two-step procedure when the benefit and cost streams are very different over time (Scheraga, 1989) and from the fact that the benefits in any given year are about four times larger when the damages stemming from IQ losses are discounted at 3% rather than 7%.

Exhibit 7-5

Optimal Hazard Levels: Results for Different Amortization Assumptions

Decision Rules			Soil (ppm)		Dust (ppm)		Paint (mg/cm^2)	
			Min	Max	Min	Max	Min	Max
1.	Single Medium Plus Condition	1a.	300	1000	-	-	-	-
		1b.	-	-	300	400	-	-
		1c.	-	-	-	-	4	4
2.	2-Media Plus Condition	2a.	1,000	2,200	300	400	-	-
		2b.	700	1,000	-	-	4	4
		2c.	-	-	300	400	20	20
3.	3-Media Plus Condition		1,000	2,200	300	400	20	20

The estimated optimal hazard level for dust experiences the clearest change from the main analysis. The highest level under the two-stage procedure is 400 ppm, as opposed to an optimum of 1,200 ppm in the main analysis. The clear demarcation between the hazard levels found using the two-stage procedure and those found using the conventional 7% approach underscores how critical the decisions regarding the appropriate discount rate are. In this case, unlike in the sensitivity analysis for costs, policy-relevant outcomes for dust are significantly different between those of a model based upon one set of assumptions and those of a model based upon a credible set of alternative assumptions.

The estimated hazard level for soil is much more dependent on the amortization assumptions made.[3] At the high end of the assumed range, meaning that costs are amortized over fifty years, an optimal hazard level of 2,200 ppm for soil is estimated. At the low end, where costs are amortized over ten years, an optimal hazard level of 300 ppm is estimated, at least for a single medium decision rule for soil. The range of values is narrower once the comparison is put on more equal footing. When the comparison is restricted to the decision rule having the highest net benefits under each amortization assumption, the optimal hazard levels range from 1,000 ppm to 2,200 ppm. Exhibits 7-6 to 7-15 provide the benefit-cost results and

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[3] The amortization period is the time period over which the initial capital investment is recovered. It matters so much because the two-stage procedure shares reflects the opportunity cost of capital that cannot be put to other uses. The longer the time period over which the capital is amortized, the longer the capital is displaced. Five iterations of the two-stage discounting procedure were estimated, based on amortization periods of 10, 20, 30, 40, and 50 years respectively. The iteration based upon 50 years results in the highest present value of the aggregate abatement costs and the iteration based upon 10 years, the lowest. Consequently the 50-year version leads to the least stringent hazard levels and the 10-year one to the most stringent levels.

abatement distributions for each of the five amortization analyses: 50, 40, 30, 20, and 10 years. These show that the turning point, from an optimal hazard level for soil of 2,200 ppm to one of 1,000 ppm occurs between the analysis based upon a thirty-year period and that based upon a twenty-year period. This finding raises the question of whether a choice between the higher and lower hazard levels can be justified by definitively establishing what the appropriate amortization period is.

The appropriate amortization period depends on what is assumed about the economic depreciation of the lead abatement. Viewed as a form of home improvement, the lead abatement can add to the capital value of the home. The capital value reflects the present discounted value of the stream of services that come from the lead abatement in the future. When those future services no longer have value, the capital is fully depreciated.

Determining when the lead abatement no longer provides services of value is difficult. At one extreme, all valuable services disappear when the home, because it is to be replaced, is destroyed. The frequency of such an occurence can be estimated from the predicted disappearance rate for homes. In this analysis, homes are assumed to have half-lives greater than the longest amortization period, seeming to indicate that an amortization period of fifty years should be used. Still, this example offers insufficient guidance since the value of having a lead-abated home could be zero even if the home is still standing. For example, if lead-free homes are in much greater relative abundance in the future, the added value of a lead-abated home should disappear.[4]

As a result, even though it is reasonable to expect that lead-abated homes could command higher prices in the near future, it is unknown when the housing market will no longer place an added value on a lead-abated home. It does not appear possible to make a definitive choice between the more stringent optimal hazard levels based upon twenty or fewer years for amortization and the less stringent levels based upon thirty or more years of amortization.[5]

As for other rules which do not estimate optimal hazard levels, the amortization assumptions vary in their significance. They are mostly irrelevant for the voluntary optimum. The two-stage discounting procedure is significant only because of the magnitude of the estimated net benefits and the numbers and types of abatements. The net benefits

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4 Even today in urban housing markets where there are relatively few homes with lead contamination the market value of a lead-abated activities would be small.

5 As a last resort, it might appear that a case could be made that the relevant time period is no more than twenty years based upon the length of payback periods of home improvement loans and of loans made to real estate developers and landlords. Each of these have been asserted to be less than twenty years typically. However, these norms are not directly linked to the value of the services from the home improvement, which can last longer than the life of the loan. Even if in fifteen years the investment is fully recovered for the homeowner who initiated the home improvement, and capital is no longer displaced, the subsequent owner may still pay a premium for the home because of the improvement. Once again, whether this is the case depends on the value that the housing market places on lead-abated homes at that time. Consequently, it does not seem that the choice between amortizing over twenty years or thirty years can be settled by appealing to current loan practices.

range from $364 to $409 billion, or approximately eleven to twelve times larger. At these levels, it is not surprising that more expensive abatements that had not been chosen before are now chosen, at least to a small degree. While more than 86% of the choices are still nonrecurrent dust abatements, all abatement alternatives are chosen under the 20-year, 30-year, and 40-year amortization analyses and all but one in the other two analyses. Finally, it should be noted that the two-staged procedure does not change the relative ranking of the voluntary optimum among all the decision rules considered. Furthermore, in absolute terms, the gap between the net benefits of the voluntary optimum and those of the other rules actually grows by a factor of three.

For the paint condition rule, the amortization assumptions in the two-stage discounting procedure matter since they determine the difference between circumstances where the net benefits are even more negative than under the main analysis (-$24 billion versus -$17 billion), as is the case when amortization takes place over fifty years, and circumstances where the net benefits are positive for the first time ($0.6 billion), as is the case when an amortization of ten years is assumed. These findings do not change the general conclusion from the main analysis that other decision rules have a far stronger economic justification than the paint condition rule does.

In conclusion, the two-stage discounting procedure has the greatest implications for choosing hazard levels under Section 403 because it raises the possibility of a wider range of potentially optimal hazard levels for dust and soil. The gap for the dust hazard level ranges from 300 ppm to 1,200 ppm.[6] For the soil hazard level, the gap ranges from 1,000 ppm to 2,300 ppm. The current analysis cannot categorically support the selection of <u>one</u> hazard level for dust and soil from each of these ranges.

Several important things remain constant between the main analysis and this sensitivity analysis. The voluntary optimum is far away the rule generating the highest net benefits and the paint condition rule typically the least (and virtually always negative). The types of decision rules that involve hazard levels for dust and soil and that have the highest net benefits are generally the same under the two-stage procedure as they are in the main analysis. They are the single-medium dust rule, the two-media rules based upon soil and dust and upon dust and paint, and the three-media rule.

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[6] Although the amortization discussion focussed on its influence on the optimal soil hazard level, it also matters to the question of which dust hazard level is optimal. A level of 400 ppm is optimal if amortization periods of forty or fifty years are assumed, and 300 ppm otherwise.

Exhibit 7-6

Benefit-Cost Results for Five Alternative Decision Rules, Two Stage Discounting: 50 Years

Decision Rules			Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Benefits ($ million)	Abatement Costs ($ million)	Net Benefits (Exclusive of Testing Costs) ($ million)	Total Number of Abatements (1000s)	Number of Abatements with Negative Net Benefits (1000s)
1.	Voluntary Optimum		-	-	-	No	501,319	136,957	364,362	79,268	0
2.	Paint Condition Only		-	-	-	Yes	46,748	71,216	(24,467)	7,063	5,667
3.	Single Medium Plus Condition	3a.	1,000	-	-	Yes	119,001	113,688	5,313	11,586	5,779
		3b.	-	400	-	Yes	462,385	205,427	256,959	43,883	8,684
		3c.	-	-	4	Yes	123,802	134,544	(10,743)	12,262	8,034
4.	2-Media Plus Condition	4a.	2,200	400	-	Yes	462,385	205,427	256,959	43,883	8,684
		4b.	1,000	-	4	Yes	179,780	168,169	11,611	15,869	8,034
		4c.	-	400	20	Yes	462,766	206,359	256,408	43,983	8,784
5.	3-Media Plus Condition		2,200	400	20	Yes	462,766	206,359	256,408	43,983	8,784

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of mg/cm² level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit 7-7

Distribution of Abatement Choices for Five Alternative Decision Rules, Two Stage Discounting: 50 Years

Decision Rules			Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Number of Homes Abated by Abatement Type (1000s)										
							HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NR D	Total
1.	Voluntary Optimum					No	367	187	1,808	3,616	2,744	21	0	8	16	70,500	79,268
2.	Paint Condition Only		-	-	-	Yes	4,137	2,521	0	0	0	161	126	36	82	0	7,063
3.	Single Medium Plus Condition	3a.	1,000	-	-	Yes	4,137	2,507	921	3,534	0	228	126	36	96	0	11,586
		3b.	-	400	-	Yes	4,463	1,990	1,584	2,762	5,681	375	803	27	0	26,198	43,883
		3c.	-	-	4	Yes	7,049	3,806	0	0	0	512	486	92	317	0	12,262
4.	2-Media Plus Condition	4a.	2,200	400	-	Yes	4,463	1,990	1,584	2,762	5,681	375	803	27	0	26,198	43,883
		4b.	1,000	-	4	Yes	7,049	3,748	780	2,828	0	512	486	92	375	0	15,869
		4c.	-	400	20	Yes	4,524	2,030	1,584	2,762	5,681	375	803	27	0	26,198	43,983
5.	3-Media Plus Condition		2,200	400	20	Yes	4,524	2,030	1,584	2,762	5,681	375	803	27	0	26,198	43,983

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Abatement Codes
HP = High Paint Abatement
LP = Low Paint Abatement
HS = High Soil Abatement
LS = Low Soil Abatement
RD = Recurrent Dust Abatement
HP/HS = High Paint, High Soil Abatements
HP/LS = High Paint, Low Soil Abatements
LP/HS = Low Paint, High Soil Abatements
LP/LS = Low Paint, Low Soil Abatements
NR D = Nonrecurrent Dust Abatement

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of mg/cm² level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit 7-8

Benefit-Cost Results for Five Alternative Decision Rules, Two Stage Discounting: 40 Years

Decision Rules			Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Benefits ($ million)	Abatement Costs ($ million)	Net Benefits (Exclusive of Testing Costs) ($ million)	Total Number of Abatements (1000s)	Number of Abatements with Negative Net Benefits (1000s)
1.	Voluntary Optimum		-	-	-	No	502,912	132,648	370,264	79,307	0
2.	Paint Condition Only		-	-	-	Yes	47,301	66,892	(19,591)	7,063	5,629
3.	Single Medium Plus Condition	3a.	1,000	-	-	Yes	119,554	108,363	11,191	11,586	5,740
		3b.	-	400	-	Yes	462,385	196,613	265,772	43,883	8,628
		3c.	-	-	4	Yes	126,107	127,849	(1,742)	12,262	7,929
4.	2-Media Plus Condition	4a.	2,200	400	-	Yes	462,385	196,613	265,772	43,883	8,628
		4b.	1,000	-	4	Yes	182,085	160,678	21,406	15,869	7,929
		4c.	-	400	20	Yes	462,766	197,480	265,286	43,983	8,728
5.	3-Media Plus Condition		2,200	400	20	Yes	462,766	197,480	265,286	43,983	8,728

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of mg/cm² level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit 7-9

Distribution of Abatement Choices for Five Alternative Decision Rules, Two Stage Discounting: 40 Years

Decision Rules		Soil (ppm)	Dust (ppm)	Paint (mg/cm^2)	Nonintact Paint Abatement Recommended	Number of Homes Abated by Abatement Type (1000s)										
						HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NR D	Total
1. Voluntary Optimum					No	488	165	1,808	3,557	2,744	21	0	8	74	70,441	79,307
2. Paint Condition Only		-	-	-	Yes	4,188	2,470	0	0	0	170	126	27	82	0	7,063
3. Single Medium Plus Condition	3a.	1,000	-	-	Yes	4,188	2,457	921	3,534	0	237	126	27	96	0	11,586
	3b.	-	400	-	Yes	4,463	1,990	1,584	2,762	5,681	375	803	27	0	26,198	43,883
	3c.	-	-	4	Yes	7,258	3,596	0	0	0	550	486	54	317	0	12,262
4. 2-Media Plus Condition	4a.	2,200	400	-	Yes	4,463	1,990	1,584	2,762	5,681	375	803	27	0	26,198	43,883
	4b.	1,000	-	4	Yes	7,258	3,538	780	2,828	0	550	486	54	375	0	15,869
	4c.	-	400	20	Yes	4,524	2,030	1,584	2,762	5,681	375	803	27	0	26,198	43,983
5. 3-Media Plus Condition		2,200	400	20	Yes	4,524	2,030	1,584	2,762	5,681	375	803	27	0	26,198	43,983

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm^2 for paint.

Abatement Codes

HP = High Paint Abatement
LP = Low Paint Abatement
HS = High Soil Abatement
LS = Low Soil Abatement
RD = Recurrent Dust Abatement
HP/HS = High Paint, High Soil Abatements
HP/LS = High Paint, Low Soil Abatements
LP/HS = Low Paint, High Soil Abatements
LP/LS = Low Paint, Low Soil Abatements
NR D = Nonrecurrent Dust Abatement

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of mg/cm^2 level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit 7-10

Benefit-Cost Results for Five Alternative Decision Rules, Two Stage Discounting: 30 Years

Decision Rules			Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Benefits ($ million)	Abatement Costs ($ million)	Net Benefits (Exclusive of Testing Costs) ($ million)	Total Number of Abatements (1000s)	Number of Abatements with Negative Net Benefits (1000s)
1.	Voluntary Optimum		-	-	-	No	512,547	134,511	378,036	79,408	0
2.	Paint Condition Only		-	-	-	Yes	48,663	62,418	(13,755)	7,063	5,451
3.	Single Medium Plus Condition	3a.	1,000	-	-	Yes	121,102	102,885	18,217	11,586	5,576
		3b.	-	300	-	Yes	539,335	234,110	305,225	51,978	9,052
		3c.	-	-	4	Yes	131,779	122,576	9,203	12,282	7,680
4.	2-Media Plus Condition	4a.	2,200	300	-	Yes	535,036	253,424	281,613	51,978	9,944
		4b.	700	-	4	Yes	188,535	155,221	33,314	15,869	7,694
		4c.	-	300	20	Yes	535,210	253,630	281,580	51,978	9,944
5.	3-Media Plus Condition		2,200	300	20	Yes	535,210	253,630	281,580	51,978	9,944

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of mg/cm² level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit 7-11

Distribution of Abatement Choices for Five Alternative Decision Rules, Two Stage Discounting: 30 Years

Decision Rules			Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Number of Homes Abated by Abatement Type (1000s)										
							HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NR D	Total
1.	Voluntary Optimum					No	1,532	213	2,319	3,444	1,684	112	172	8	16	69,907	79,406
2.	Paint Condition Only		-	-	-	Yes	4,290	2,368	0	0	0	170	185	27	24	0	7,063
3.	Single Medium Plus Condition	3a.	1,000	-	-	Yes	4,290	2,354	921	3,534	0	251	185	27	24	0	11,586
		3b.	-	300	-	Yes	6,082	1,885	5,827	0	4,154	1,952	0	27	0	32,050	51,978
		3c.	-	-	4	Yes	7,684	3,171	0	0	0	550	730	54	74	0	12,262
4.	2-Media Plus Condition	4a.	2,200	300	-	Yes	5,647	1,885	5,548	0	5,046	1,775	0	27	0	32,050	51,978
		4b.	700	-	4	Yes	7,684	3,113	780	2,828	0	608	730	54	74	0	15,869
		4c.	-	300	20	Yes	5,748	1,885	5,548	0	4,945	1,775	0	27	0	32,050	51,978
5.	3-Media Plus Condition		2,200	300	20	Yes	5,748	1,885	5,548	0	4,945	1,775	0	27	0	32,050	51,978

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Abatement Codes

HP = High Paint Abatement
LP = Low Paint Abatement
HS = High Soil Abatement
LS = Low Soil Abatement
RD = Recurrent Dust Abatement

HP/HS = High Paint, High Soil Abatements
HP/LS = High Paint, Low Soil Abatements
LP/HS = Low Paint, High Soil Abatements
LP/LS = Low Paint, Low Soil Abatements
NR D = Nonrecurrent Dust Abatement

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of mg/cm² level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit 7-12

Benefit-Cost Results for Five Alternative Decision Rules, Two Stage Discounting: 20 Years

Decision Rules			Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Benefits ($ million)	Abatement Costs ($ million)	Net Benefits (Exclusive of Testing Costs) ($ million)	Total Number of Abatements (1000s)	Number of Abatements with Negative Net Benefits (1000s)
1.	Voluntary Optimum		-	-	-	No	533,242	142,387	390,854	79,689	0
2.	Paint Condition Only		-	-	-	Yes	49,546	56,524	(6,978)	7,063	5,150
3.	Single Medium Plus Condition	3a.	300	-	-	Yes	260,929	228,815	32,114	18,777	9,684
		3b.	-	300	-	Yes	539,335	234,110	305,225	51,978	9,052
		3c.	-	-	4	Yes	135,152	112,951	22,200	12,262	7,274
4.	2-Media Plus Condition	4a.	1,000	300	-	Yes	540,104	234,617	305,487	52,045	9,052
		4b.	700	-	4	Yes	236,203	183,622	52,581	18,171	8,790
		4c.	-	300	20	Yes	539,335	234,110	305,225	51,978	9,052
5.	3-Media Plus Condition		1,000	300	20	Yes	540,104	234,617	305,487	52,045	9,052

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of mg/cm² level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit 7-13

Distribution of Abatement Choices for Five Alternative Decision Rules, Two Stage Discounting: 20 Years

Decision Rules		Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Number of Homes Abated by Abatement Type (1000s)										
						HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NR D	Total
1. Voluntary Optimum					No	2,198	190	4,670	1,092	1,387	169	188	8	0	69,786	79,689
2. Paint Condition Only		-	-	-	Yes	4,317	2,319	0	0	0	205	188	27	8	0	7,063
3. Single Medium Plus Condition	3a.	300	-	-	Yes	3,612	1,998	9,198	0	0	3,745	0	223	0	0	18,777
	3b.	-	300	-	Yes	6,082	1,885	5,827	0	4,154	1,952	0	27	0	32,050	51,978
	3c.	-	-	4	Yes	7,795	2,966	0	0	0	656	783	54	8	0	12,262
4. 2-Media Plus Condition	4a.	1,000	300	-	Yes	6,082	1,885	5,895	0	4,154	1,952	0	27	0	32,050	52,045
	4b.	700	-	4	Yes	7,649	2,779	5,433	477	0	894	783	150	8	0	18,171
	4c.	-	300	20	Yes	6,082	1,885	5,827	0	4,154	1,952	0	27	0	32,050	51,978
5. 3-Media Plus Condition		1,000	300	20	Yes	6,082	1,885	5,895	0	4,154	1,952	0	27	0	32,050	52,045

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Abatement Codes

HP = High Paint Abatement
LP = Low Paint Abatement
HS = High Soil Abatement
LS = Low Soil Abatement
RD = Recurrent Dust Abatement

HP/HS = High Paint, High Soil Abatements
HP/LS = High Paint, Low Soil Abatements
LP/HS = Low Paint, High Soil Abatements
LP/LS = Low Paint, Low Soil Abatements
NR D = Nonrecurrent Dust Abatement

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of mg/cm² level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit 7-14

Benefit-Cost Results for Five Alternative Decision Rules, Two Stage Discounting: 10 Years

Decision Rules			Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Benefits ($ million)	Abatement Costs ($ million)	Net Benefits (Exclusive of Testing Costs) ($ million)	Total Number of Abatements (1000s)	Number of Abatements with Negative Net Benefits (1000s)
1.	Voluntary Optimum		-	-	-	No	558,772	150,119	408,653	80,842	0
2.	Paint Condition Only		-	-	-	Yes	52,477	51,843	635	7,063	5,023
3.	Single Medium Plus Condition	3a.	300	-	-	Yes	263,342	200,086	63,257	18,777	8,386
		3b.	-	300	-	Yes	543,290	210,539	332,751	51,978	8,352
		3c.	-	-	4	Yes	140,161	103,225	36,936	12,262	6,512
4.	2-Media Plus Condition	4a.	1,000	300	-	Yes	544,058	210,978	333,080	52,045	8,352
		4b.	700	-	4	Yes	238,581	162,501	76,081	18,171	7,281
		4c.	-	300	20	Yes	543,290	210,539	332,751	51,978	8,352
5.	3-Media Plus Condition		1,000	300	20	Yes	544,058	210,978	333,080	52,045	8,352

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of mg/cm² level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefit.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit 7-15

Distribution of Abatement Choices for Five Alternative Decision Rules, Two Stage Discounting: 10 Years

Decision Rules			Soil (ppm)	Dust (ppm)	Paint (mg/cm²)	Nonintact Paint Abatement Recommended	Number of Homes Abated by Abatement Type (1000s)										
							HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NR D	Total
1.	Voluntary Optimum					No	2,735	178	6,038	537	952	652	657	8	0	69,085	80,842
2.	Paint Condition Only		-	-	-	Yes	4,227	2,202	0	0	0	398	188	49	0	0	7,063
3.	Single Medium Plus Condition	3a.	300	-	-	Yes	3,682	1,928	9,012	0	0	3,958	0	196	0	0	18,777
		3b.	-	300	-	Yes	6,645	1,871	5,827	0	3,264	2,279	0	41	0	32,050	51,978
		3c.	-	-	4	Yes	7,665	2,764	0	0	0	975	783	76	0	0	12,262
4.	2-Media Plus Condition	4a.	1,000	300	-	Yes	6,645	1,871	5,895	0	3,264	2,279	0	41	0	32,050	52,045
		4b.	700	-	4	Yes	7,629	2,682	5,498	411	0	1,011	783	158	0	0	18,171
		4c.	-	300	20	Yes	6,645	1,871	5,827	0	3,264	2,279	0	41	0	32,050	51,978
5.	3-Media Plus Condition		1,000	300	20	Yes	6,645	1,871	5,895	0	3,264	2,279	0	41	0	32,050	52,045

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Abatement Codes

HP = High Paint Abatement
LP = Low Paint Abatement
HS = High Soil Abatement
LS = Low Soil Abatement
RD = Recurrent Dust Abatement

HP/HS = High Paint, High Soil Abatements
HP/LS = High Paint, Low Soil Abatements
LP/HS = Low Paint, High Soil Abatements
LP/LS = Low Paint, Low Soil Abatements
NR D = Nonrecurrent Dust Abatement

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of mg/cm² level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

7.4 SUPPLEMENTAL BENEFITS FOR ADULTS AND EXISTING CHILDREN

The main analysis presented in this report was based upon a model developed to consider the benefits to children by reducing lead exposure from the time of birth until the age of seven years through the abatement of lead contamination. Not only was the risk assessment focused on this population alone but the behavioral assumptions regarding lead abatement were integrally linked to the impending births of children. This model structure reflects the fact that this population has been considered a primary target for measures to prevent residential exposures to lead-contaminated paint, dust, and soil. There are however other populations that may benefit from reducing lead exposures.

One population that has not been included in the main analysis consists of children under the age of seven who are already present in homes during the first seven years of the modeling time frame. Because the model is currently structured to consider only lead abatements in anticipation of a new child being born into homes, these "existing" children do not serve as triggers for making an abatement decision nor are the benefits from any abatement calculated for them. These children need special attention only in the first seven years of the fifty years of analysis since in subsequent years all children younger than seven years old were born during the time period being modelled.

Little is known about the size of the benefits to children who have been exposed to high lead levels during, for example, the first three-and-half years of their lives but avoid these exposures in the remaining three-and-half years during which IQ development, in particular, could have been inhibited. For the purposes of this sensitivity analysis, the original assumption regarding the motivation for abatement - the upcoming birth of a child - was maintained but the benefits from abatement for the child about to be born were supplemented by an estimate of the benefits to the expected number of children under seven already in the household. The benefits for these existing children were a prorated portion of the benefits expected for a newborn. In the first year of the model, for example, the representative existing child was assumed to be three-and-a-half years old and to gain one-half the benefit that a newborn would from abatement.

Other populations for whom potential benefits of lead abatements are not currently considered in the model are older children and adults. Adverse health effects are associated with elevated blood lead levels in individuals over the age of seven, and there is a considerable body of information on the dose-response relationships between blood lead levels in adults and blood pressure. There is, however, scant information on the relationships between lead levels in paint, soil and dust and blood lead levels for populations over the age of seven (the IEUBK model only considers children up to seven years of age). It is therefore difficult to quantify the changes in blood lead levels and the coincident changes in health status of adults associated with residential lead abatements. As a "placeholder" for estimating the potential impacts of lead abatements, a method has been developed that draws upon information provided in recent report by the Centers for Disease Control (CDC). The CDC cites findings of Bornschein that the blood lead levels of pregnant women in homes with and without lead-based paint differed by 2.13 μg/dL (Centers for Disease Control, 1991). (As noted in Chapter 3, this information was also used in the main analysis for the computation of the incidence of neonatal mortality.) In this analysis, this difference is applied to the case of adults living in homes where lead-based paint is abated in connection with an impending birth to calculate the reduced probabilities of hypertension-related effects. Reduced hypertension-related mortality is valued using $2 million per statistical life saved. Certain reduced morbidity effects (non-fatal stroke and coronary heart disease) are valued using 32% of the value of a statistical life saved. Avoided hypertension is valued using estimates of medical costs avoided. In sum, the per-abatement adult benefit is estimated as $5,814. More in-depth details can be found in (Abt Associates, Inc., 1993).

The overall estimates that derive from supplementing the newborn child benefits in the main analysis with benefits to existing children and adults should be viewed as illustrative only, in light of the unrefined and somewhat arbitrary assumptions needed to generate the supplemental benefit estimates. The benefit-cost results are presented in Exhibit 7-16 and the distribution of abatements selected in Exhibit 7-17.

For all decision rules, the net benefits are higher in this sensitivity analysis than they were under the main analysis of this report (Exhibits 6-18 and 6-19). This is mostly attributable to the inclusion of the adult benefits rather than the inclusion of the benefits to existing children. Furthermore, the net benefits are positive for all decision rules, a rare finding seen in only other version of the analysis (the two-stage discounting example based on an amortization period of 10 years). This outcome underscores how radical a departure the addition of adult benefits is from the main analysis. In the case of the voluntary optimum, the net benefits are $7 billion higher. For the remaining decision rules, the changes are even more dramatic. The net benefits are $20 to $27 billion higher than they were for these rules in the main analysis.

In two cases (the paint condition only rule and the single-medium rule based upon soil plus non-intact paint abatement), the number of abatements induced did not change. The net benefits of these abatements changed dramatically though because of the supplemental adult benefits associated with paint abatement. The number of abatements under the voluntary optimum increased by 9 million homes. In the remainder of the cases the numbers of abatements rose by 5 to 28 million homes.

Although the change in benefits from the main analysis was only directly associated with paint abatement, increases in the number of abatements were not restricted to paint abatement. As shown in Exhibit 7-17, nonrecurrent dust abatement, abatements that included high-end paint abatement, and low-end soil abatement showed the largest increases from the results of the main analysis. Other forms of abatement in addition to paint abatement increased in the optimum because formerly the houses needing paint abatement served as a "roadblock" to going to lower soil or dust hazard levels in the optimum. These houses had negative net benefits from abatement and lowered the aggregate net benefits in the main analysis even though other houses, with the same soil and/or dust levels, had positive net benefits from soil or dust abatement. In the aggregate, the latter were not large enough to outweigh the negative net benefits of the former. Consequently, in the main analysis, higher hazard levels had higher aggregate net benefits. Only once the benefits of paint abatement were supplemented by the adult benefits was it possible for the aggregate net benefits of more stringent soil and dust hazard levels to be the highest.

This phenomenon helps to explain why the hazard levels for soil and dust could decline when only the benefits for paint abatement were increased in this sensitivity analysis. The dust hazard level exhibited the most consistent decline, from 1,200 ppm in the main analysis to 400 ppm in all cases in this sensitivity analysis. This reduction in the optimal dust level may have also been assisted by the possibility that lower dust levels can be achieved through paint abatement. The fact that the optimal three-media decision rule (1,400/400/20) and the optimal two-media decision rule involving dust and paint (--/400/20) both induce large numbers of paint abatements while the paint hazard level remains high seems to be consistent with this conclusion. These two decision rules and the other two that involve a dust hazard level (the single-medium rule (--/400/--) and the two-media rule for soil and dust (1,400/400/--)) have net benefits of approximately $29.5 billion, the highest among the rules defining hazard levels.

In view of the uncertainties associated with the benefits for adults and existing children in this particular sensitivity analysis, it is important to weigh its implications for policymaking very carefully. Of the three sensitivity analyses presented in this chapter, this one may rest on the weakest analytical footing. However, since the optimal hazard levels identified in this analysis are consistent with the lower bounds of the optimal hazard levels identified in the previous two sensitivity analyses, the burden of proof for the findings of this particular sensitivity analysis is not high.

This analysis found an optimal hazard level for soil of 1,400 ppm. A level of 1,500 ppm was optimal in the low cost scenario while a level of 1,000 ppm was the lowest optimal hazard level under the two-stage discounting procedure. The optimal hazard level for dust in this sensitivity analysis was 400 ppm. The optimal level was higher in the high and low cost scenarios (1,200 ppm) but the lower bound of the optimal hazard levels under the various two-stage discounting scenarios was comparable (300 ppm). The experience with paint hazard levels under this sensitivity analysis reproduced that of the two-stage procedure, where the optimal hazard level was variously 4 or 20 mg/cm^2, depending upon the decision rule, but the highest net benefits were based upon 20 mg/cm^2.

Taken together, the three sensitivity analyses presented in this chapter raise the possibility of a wider range of potentially optimal hazard levels than the findings in the main analysis imply. The optimal dust hazard level may be as low as 300 ppm or as high as 1,200 ppm. The main analysis found a dust hazard level of 1,200 ppm. The optimal soil hazard level may be as low as 1,000 ppm or as high as 2,300 ppm. The main analysis found a soil hazard level of 2,300 ppm. In the main analysis, and in these sensitivity analyses, the highest net benefits for paint were associated with a hazard level of mg/cm^2. Finally, a qualitative hazard level based upon paint condition typically entails negative net benefits with the exception of two cases: this particular sensitivity analysis which linked supplemental benefits to paint abatement specifically and, the shortest-term amortization case (10 years) under the two-stage discounting procedure. These two cases still seem rare enough to raise doubts about the desirability of a paint condition criterion given the paint abatement options constructed for this analysis.

Exhibit 7 - 16

Benefit-Cost Results for Five Alternative Decision Rules, Adults and Existing Children

Decision Rules			Soil (ppm)	Dust (ppm)	Paint mg/cm^2	Nonintact Paint Abatement Recommended	Benefits ($ million)	Abatement Costs ($ million)	Net Benefits (Exclusive of Testing Costs) ($ million)	Total Number of Abatements (1000s)	Number of Abatements with Negative Net Benefits (1000s)
1.	Voluntary Optimum		-	-	-	No	100,116	58,720	41,396	54,558	0
2.	Paint Condition Only		-	-	-	Yes	37,015	34,838	2,177	7,063	4,241
3.	Single Medium Plus Condition	3a.	2,300	-	-	Yes	44,081	41,192	2,890	8,069	4,710
		3b.	-	400	-	Yes	123,754	94,262	29,492	43,883	11,168
		3c.	-	-	4	Yes	70,910	62,053	8,858	12,262	5,733
4.	2-Media Plus Condition	4a.	1,400	400	-	Yes	123,754	94,262	29,492	43,883	11,168
		4b.	2,300	-	4	Yes	72,853	63,473	9,380	12,673	5,733
		4c.	-	400	20	Yes	124,247	94,749	29,498	43,983	11,168
5.	3-Media Plus Condition		1,400	400	20	Yes	124,247	94,749	29,498	43,983	11,168

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm^2 for paint.

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of XRF level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefit.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

Exhibit 7 - 17

Distribution of Abatement Choices for Five Alternative Decision Rules, Adults and Existing Children

Decision Rules			Soil (ppm)	Dust (ppm)	Paint mg/cm²	Nonintact Paint Abatement Recommended	Number of Homes Abated by Abatement Type (1000s)										
							HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NR D	Total
1.	Voluntary Optimum					No	8,928	0	0	411	0	0	314	0	0	44,905	54,558
2.	Paint Condition Only		-	-	-	Yes	6,876	0	0	0	0	0	188	0	0	0	7,063
3.	Single Medium Plus Condition	3a.	2,300	-	-	Yes	6,876	0	0	411	0	0	783	0	0	0	8,069
		3b.	-	400	-	Yes	12,439	0	967	3,379	879	233	1,269	0	0	24,716	43,883
		3c.	-	-	4	Yes	11,479	0	0	0	0	0	783	0	0	0	12,262
4.	2-Media Plus Condition	4a.	1,400	400	-	Yes	12,439	0	967	3,379	879	233	1,269	0	0	24,716	43,883
		4b.	2,300	-	4	Yes	11,479	0	0	411	0	0	783	0	0	0	12,673
		4c.	-	400	20	Yes	12,540	0	967	3,379	879	233	1,269	0	0	24,716	43,983
5.	3-Media Plus Condition		1,400	400	20	Yes	12,540	0	967	3,379	879	233	1,269	0	0	24,716	43,983

Candidate hazard levels examined ranged up to 3000 ppm for soil, 2000 ppm for dust, and 22 mg/cm² for paint.

Abatement Codes

HP = High Paint Abatement
LP = Low Paint Abatement
HS = High Soil Abatement
LS = Low Soil Abatement
RD = Recurrent Dust Abatement
HP/HS = High Paint, High Soil Abatements
HP/LS = High Paint, Low Soil Abatements
LP/HS = Low Paint, High Soil Abatements
LP/LS = Low Paint, Low Soil Abatements
NR D = Nonrecurrent Dust Abatement

Voluntary Optimum: Each home selects abatement (or no abatement) that has the highest net benefits

Paint Condition Only: Abatement is recommended for homes with more than five square feet of lead-based paint in nonintact condition, regardless of XRF level or net benefits. Homeowners choose the paint abatement method that generates the highest net benefits.

Single Medium: Within the full range of individual soil, dust, and paint hazard levels that could be set as a threshold for action, with no constraints placed on the other two media, the levels specified in the table maximize net benefits.

2-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, with no restriction on the other medium, the levels specified in the table maximize net benefits.

3-Media: Within the full range of individual soil, dust, and paint hazard level combinations that could be set as a threshold for action, the levels specified in the table maximizes net benefits.

7.5 REFERENCES

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7.A APPENDIX

As discussed in Section 7.1, a two-stage discounting procedure was used as an alternative to the straight seven percent discounting presented in Chapters 4-6. Exhibit 7.A-1 shows the unit costs calculated for each of the ten abatement scenarios using amortization of twenty and thirty years. Because the reflect the social costs of displacing capital, these unit costs are higher than those calculated using a seven percent discount rate as shown in Exhibits 4-5 and 4-6.

Exhibit 7.A-1

Summary of Abatement Strategy Unit Costs Using Two Stage Discounting

Abatement Scenario	Estimate Level	Unit Cost by Amortization Period				
		10 Year	20 Year	30 Year	40 Year	50 Year
High-end Paint Abatement	High	$15,485	$17,905	$20,139	$22,106	$23,771
	Medium	$12,752	$14,745	$16,585	$18,205	$19,576
	Low	$10,020	$11,585	$13,031	$14,304	$15,381
Low-end Paint Abatement	High	$4,554	$5,266	$5,923	$6,502	$6,991
	Medium	$3,340	$3,862	$4,344	$4,768	$5,127
	Low	$2,125	$2,457	$2,764	$3,034	$3,263
Non-Recurrent Dust	High	$1,457	$1,685	$1,895	$2,081	$2,237
	Medium	$911	$1,053	$1,185	$1,300	$1,398
	Low	$364	$421	$474	$520	$559

Abatement Scenario	Ten Year	Monthly	Total Cost Estimate
Recurrent Dust	High	High	$25,708
	High	Low	$15,065
	Low	High	$22,606
	Low	Low	$11,964
	Medium	High	$24,159
	Medium	Low	$13,515

Exhibit 7.A-1

Summary of Abatement Strategy Unit Costs Using Two Stage Discounting

Abatement Scenario	Estimate Level	Unit Cost by Amortization Period				
High-end Soil Abatement	High cost	High cost	High cost	High cost	High cost	High cost
	>2000 ppm and exterior paint	$39,897	$46,132	$51,888	$56,956	$61,245
	≤2000 ppm and exterior paint	$24,715	$28,578	$32,143	$35,283	$37,940
	>2000 ppm and no exterior paint	$27,752	$32,089	$36,092	$39,618	$42,601
	≤2000 ppm and no exterior paint	$12,570	$14,535	$16,348	$17,945	$19,296
	Medium cost	Medium cost	Medium cost	Medium cost	Medium cost	Medium cost
	>2000 ppm and exterior paint	$26,005	$30,069	$33,821	$37,125	$39,920
	≤2000 ppm and exterior paint	$15,786	$18,253	$20,531	$22,536	$24,233
	>2000 ppm and no exterior paint	$19,933	$23,048	$25,923	$28,455	$30,598
	≤2000 ppm and no exterior paint	$9,714	$11,232	$12,633	$13,867	$14,911
	Low cost	Low cost	Low cost	Low cost	Low cost	Low cost
	>2000 ppm and exterior paint	$15,757	$18,220	$20,493	$22,495	$24,188
	≤2000 ppm and exterior paint	$10,501	$12,142	$13,657	$14,991	$16,119
	>2000 ppm and no exterior paint	$12,114	$14,007	$15,754	$17,293	$18,595
	≤2000 ppm and no exterior paint	$6,857	$7,929	$8,918	$9,789	$10,526
Low-end Soil Abatement	High - $19,178 Medium - $13,310 Low - $7,442					

Exhibit 7.A-1

Summary of Abatement Strategy Unit Costs Using Two Stage Discounting

Abatement Scenario	Estimate Level	Unit Cost by Amortization Period				
High-end Paint and High-end Soil	High cost	High cost	High cost	High cost	High cost	High cost
	>2000 ppm and exterior paint	$55,382	$64,037	$72,027	$79,062	$85,016
	≤2000 ppm and exterior paint	$40,200	$46,483	$52,282	$57,389	$61,711
	>2000 ppm and no exterior paint	$43,237	$49,994	$56,231	$61,724	$66,372
	≤2000 ppm and no exterior paint	$28,055	$32,440	$36,487	$40,051	$43,067
	Medium cost	Medium cost	Medium cost	Medium cost	Medium cost	Medium cost
	>2000 ppm and exterior paint	$38,757	$44,814	$50,406	$55,330	$59,496
	≤2000 ppm and exterior paint	$28,538	$32,998	$37,116	$40,741	$43,809
	>2000 ppm and no exterior paint	$32,685	$37,793	$42,508	$46,660	$50,174
	≤2000 ppm and no exterior paint	$22,466	$25,977	$29,218	$32,072	$34,487
	Low cost	Low cost	Low cost	Low cost	Low cost	Low cost
	>2000 ppm and exterior paint	$25,777	$29,806	$33,524	$36,799	$39,569
	≤2000 ppm and exterior paint	$20,521	$23,728	$26,688	$29,295	$31,500
	>2000 ppm and no exterior paint	$22,134	$25,593	$28,785	$31,597	$33,967
	≤2000 ppm and no exterior paint	$16,877	$19,515	$21,949	$24,093	$25,907
High-end Paint and Low-end Soil	High	$34,662	$37,083	$39,317	$41,284	$42,949
	Medium	$26,062	$28,055	$29,895	$31,515	$32,886
	Low	$17,462	$19,027	$20,473	$21,746	$22,823

Exhibit 7.A-1

Summary of Abatement Strategy Unit Costs Using Two Stage Discounting

Abatement Scenario	Estimate Level	Unit Cost by Amortization Period				
Low-end Paint and High-end Soil	High cost	High cost	High cost	High cost	High cost	High cost
	>2000 ppm and exterior paint	$44,451	$51,398	$57,810	$63,458	$68,236
	≤2000 ppm and exterior paint	$29,269	$33,844	$38,066	$41,785	$44,931
	>2000 ppm and no exterior paint	$32,306	$37,355	$42,015	$46,120	$45,592
	≤2000 ppm and no exterior paint	$17,124	$19,801	$22,271	$24,446	$26,287
	Medium cost	Medium cost	Medium cost	Medium cost	Medium cost	Medium cost
	>2000 ppm and exterior paint	$29,345	$33,931	$38,165	$41,893	$45,047
	≤2000 ppm and exterior paint	$19,126	$22,115	$24,875	$27,304	$29,360
	>2000 ppm and no exterior paint	$23,273	$26,910	$30,267	$33,223	$35,725
	≤2000 ppm and no exterior paint	$13,054	$15,094	$16,977	$18,635	$20,038
	Low cost	Low cost	Low cost	Low cost	Low cost	Low cost
	>2000 ppm and exterior paint	$17,882	$20,678	$23,257	$25,529	$27,451
	≤2000 ppm and exterior paint	$12,626	$14,600	$16,421	$18,025	$19,382
	>2000 ppm and no exterior paint	$14,239	$16,465	$18,518	$20,327	$21,858
	≤2000 ppm and no exterior paint	$8,982	$10,387	$11,682	$12,823	$13,789
Low-end Paint and Low-end Soil	High	$23,732	$24,444	$25,101	$25,680	$26,169
	Medium	$16,650	$17,172	$17,654	$18,078	$18,437
	Low	$9,567	$9,900	$10,206	$10,476	$10,705

8. IMPACTS OF THE PROPOSED RULE

8.1 REGULATORY FLEXIBILITY ANALYSIS

8.1.1 Reason and Legal Basis for Agency Action

The Agency is identifying lead-based paint hazards, lead-contaminated soil and lead contaminated dust under the Housing and Community Development Act which was enacted by Congress on October 28, 1992 and contains 16 separate Titles. Title X of the Act is named the Residential Lead-Based Paint Hazard Reduction Act of 1992 and is composed of five subtitles. One of these, Subtitle B, amends the Toxic Substances Control Act (TSCA) by adding Title IV-Lead Exposure Reduction. TSCA Title IV includes twelve sections, from §401 through §412. Section 403, the subject of this analysis, reads as follows:

> **Sec. 403. Identification of Dangerous Levels of Lead**
> "Within 18 months after the enactment of this title, the Administrator shall promulgate regulations which shall identify, for purposes of this title and the Residential Lead-Based Paint Hazard Reduction Act of 1992, lead-based paint hazards, lead-contaminated dust, and lead-contaminated soil."

Section 403 by itself requires only the identification of lead hazard levels and does not require any specific action to abate residences whose contamination is above these levels. Thus a formal regulatory flexibility analysis will not be done. Instead, this section will identify small entities likely to be induced to abatement activity by the Agency's actions and discuss the availability of data to quantify the effects. The approach taken is in keeping with the Regulatory Flexibility Act charter which suggests:

> "as a principle of regulatory issuance that agencies shall endeavor, consistent with the objectives of the rule and of applicable statutes, to fit regulatory and informational requirements to the scale of businesses, organizations and governmental jurisdictions subject to regulation. To achieve this principle, agencies are required to solicit and consider flexible regulatory proposals and to explain the rationale for their actions to assure that such proposals are given serious consideration."

The hazard levels the Agency sets will generate activity in two ways. First, voluntary abatement is a likely response to the introduction of EPA these levels. This may impose a disproportionate burden on lower income homeowners and renters and is addressed by comparing income to abatement costs for individual homeowners as shown in Section 8.5. Second, the levels set in Section 403 are used throughout Title X as the basis for determining appropriate responses to the existence of lead-based hazards. The small business and government entities likely to be affected by various provisions of Title X are discussed below.

8.1.2 Definition of Small Entity and Affected Populations

The first step in the analysis is to define small entity and the affected populations in a quantitative manner in order to determine the number affected. The definition should encompass small firms, small non-profit organizations and small governments. The Section 403 regulation pertains to home-owners and landlords; in these cases, the typical definition of small business based on the number of employees is not relevant. However, the "EPA Guidelines for Implementing the Regulatory Flexibility Act" allows a re-definition of small entity to suit the regulatory circumstances if the Office of Advocacy of the Small Business Administration is consulted and public comment on the proposed alternative definitions is obtained. For this regulation we suggest the typical housing industry definition of a small landlord, one who owns less than four units, as the appropriate small business definition. Definitions based on the number of units are preferable to those based on revenue or number of employees because of the variability of the latter two per housing unit. Small not-for-profit organizations could be defined in the same manner as the small business. For small government jurisdictions, the standard definition of a population less than 50,000 would apply.

Exhibit 8-1 summarizes the discussion in Chapter 1 of the Housing and Community Development Act sections where the levels set in Section 403 are used. The final column identifies the types of entities that may be affected. The sections of Title X that are most likely to disproportionately burden small entities are Sections 1012 and 1018. The former requires reduction of hazards in rehabilitation projects receiving less than $25,000 per unit in Federal funds and abatement of hazards in those rehabilitation projects receiving more than $25,000 in Federal funds per unit. These additional hazard reduction actions could prove a financial burden. Section 1018 requires notification to the buyer of any property with a known lead-based paint hazard and gives the buyer the right to perform an inspection before being obligated to a contract for sale or lease. Small entities, housing owners, might be disproportionately affected by a decrease in market value of a home if lead is found.

EXHIBIT 8-1

Relationship of Identification of Lead Hazard Levels under § 403 with Other Provisions of the Lead-Based Paint Hazard Reduction Act

Section	Affected Housing Stock or Entity	Relationship	Small Entities Affected by §403 Hazard Levels
§1011(a)	Affordable non-public housing that is not federally owned or assisted housing	§403 Identification used to establish eligibility for receiving HUD grants for interim controls or abatement of lead-based paint hazards.	No direct effects. Indirect effect is a benefit for both large and small landlords.
§1012	Various housing receiving assistance under the Cranston-Gonzalez National Affordable Housing Act	1) §403 Identification used to require reduction of hazards in course of rehabilitation projects receiving less than $25,000 per unit in federal funds, and abatement of hazards in rehabilitation projects receiving more than $25,000 per unit. 2) §403 Identification used to establish eligibility for receiving federal funds for interim controls or abatement of lead-based paint hazards. 3) §403 Identification used to establish eligibility for including inspection and abatement costs in determining maximum monthly rents in federally assisted rental property.	Could add lead reduction or abatement costs on top of rehabilitation costs. The $25,000 ceiling is low enough that both small and large landlords will be affected. This might be a greater financial burden to small landlords.
§1013	Federally owned housing being sold	1) Housing built prior to 1960: Inspection and REQUIRED abatement of lead-based paint hazard (as identified by §403). 2) Housing built between 1960 and 1978: Inspection and written notification to buyer of all lead-based paint hazards (as identified by §403)	Federally owned housing primarily from the Resolution Trust Corporation or Veteran's Administration or Housing and Urban Development. Federal government is a large entity.
§1014	Low-income housing units under jurisdiction of Cranston-Gonzalez National Affordable Housing Act.	§403 Identification used to estimate number of housing units in a jurisdiction occupied by low-income families that have a lead-based paint hazard. Information shall be used in preparing a housing strategy .	Information dissemination only. No significant direct or indirect effect on small entities.
§1015	Private housing.	§403 Identification used by Inter-Agency Task Force to recommend programs and procedures for financing inspections and abatements.	No direct effect on small entities. Indirect effects could occur based on the policies set.

Section	Affected Housing Stock or Entity	Relationship	Small Entities Affected by §403 Hazard Levels
§1017	Federally supported inspections, risk assessments, interim controls and abatements	§403 Identification used in Guidelines for conducting federally supported lead-based paint hazard reduction.	No significant direct or indirect effects for small entities.
§1018	Sale or lease of all housing stock constructed before 1978.	Requires notification to buyer of any known lead-based paint hazards (as identified by §403). Buyer has right to perform inspection before being obligated by contract for sale or lease.	Small landlords could be burdened if the market value of house decreased due to the presence of lead; however if the market reflects the higher value of a lead free home once the market adjusts there would be no differential burden for small landlords.
§1021 TSCA Title IV, §402	Persons offering to eliminate lead-based paint hazards.	Training and certification requirements for all persons involved with identifying and eliminating lead-based paint hazards (as identified by §403).	These effects are covered under Section 402 Regulatory Flexibility Act.
§1021 TSCA Title IV, §405	Information on identifying and eliminating lead-based paint hazards.	1) Clearinghouse and hotline to provide information on identifying, reducing and eliminating lead-based paint hazards (as identified by §403). 2) Establish protocols and performance characteristics for products sold to reduce or eliminate lead-based paint hazards (as identified by §403).	No effect directly due to Section 403.
§1021 TSCA Title IV, §406	Lead Hazard Information Pamphlet.	Required pamphlet to explain lead-based paint hazards (as identified by §403) and approved methods to eliminate those hazards.	Information dissemination should have no direct effect on small businesses. This is covered under the Section 406 analysis.
§1021 TSCA Title IV, §408	All executive, legislative and judicial branches of the federal government having jurisdiction over property, or engaged in activities that may result in a lead-based paint hazard	All requirements in Lead-Based Paint Hazard Reduction Act of 1992 shall apply to all federal departments, agencies and instrumentalities.	Federal government action. No direct effect on small governments.

8.1.3 Data Availability

Data on housing ownership and financial viability of landlords is available in proportion to the amount of Federal assistance given. In general, the four levels of housing ordered by decreasing amount of Federal assistance are: Federally owned, local public housing authority owned, privately owned with public assistance, and privately owned. The information available on each of these levels is discussed below. Information on Federally owned housing such as insured properties acquired through default by the Department of Housing and Urban Development (HUD), Resolution Trust Corporation, Veteran's Administration and Department of Defense is available. However, since the Federal government is a large entity, the burden of the Title X requirements will not be considered here. Public housing is owned by over 3,400 local public housing authorities ranging in size from less than 100 units to over 9,000 units. The definition of small entity in this regard may be determined by the financial viability of the authority. Data is available on the size of public housing authorities by units, revenue and number of employees. Privately owned and Federally assisted housing consists of multifamily rental properties under Sections 236 and 221(d)(3), project-based assistance for multifamily rentals under the Section 8 Program and Farmers Home Administration owner-occupied and rental programs under Sections 502, 504 and 515. The total number of units in HUD-based multifamily programs is perhaps 1.4 million. HUD can identify inventory and age but has little information on ownership except whether the owner is a non-profit or profit entity. Project income expense data is maintained by HUD for some programs. Title X makes testing and abatement an eligible expense for locally administered programs for owner and rental rehabilitation; however, the number of rehabilitations is not known. The final housing category, private market rentals and sales are covered by two provisions of Title X. Overall, quantitative data on privately owned housing is unavailable. Large cities usually have property directories that list owners; however, they are not in a standard format and accessing the data could be difficult. In cities with rent control, such as Los Angeles and the District of Columbia, the city directories could be searched by landlord to locate all small landlords. Unfortunately, this information is not compiled and would be resource-intensive to collect.

8.1.4 Regulatory Options

Classic options available to protect small business are possible under Section 403. Because Section 403 is a TSCA regulation, benefit-cost considerations are integral in setting the regulatory levels. Exemption of certain classes of small landlords from the provisions or relaxing the standards for small entities are two possibilities. Consideration of these options must include their effect on the overall goal of Section 403, which is to set health-based hazard levels and to the intent of the law, which is to protect the public health.

8.2 PAPERWORK REDUCTION ACT ANALYSIS

Setting of the lead hazard levels in paint, soil and dust does not, of itself, generate additional reporting or record keeping requirements. Thus there is no increase in burden or costs requiring analysis under the Paperwork Reduction Act. Regulatory requirements by other Title IV sections (including sections 402 and 406) that rely on the hazard levels set under Section 403 rules are evaluated separately in other regulatory impact analyses.

8.3 TRADE IMPACTS ANALYSIS

Section 403 of TSCA Title IV identifies lead hazard levels in paint, soil and dust for the purposes of Title IV and the Residential Lead-Based Paint Hazard Reduction Act of 1992. The regulation requires certain abatement and notification activities to take place at these levels in subsets of domestic housing as was outlined in Section 1.2 Exhibit 1.1. All the entities covered are domestic and there is no anticipated direct effect on international trade. Any indirect effects are expected to be negligible. Abatements are expected in housing other than those listed in Exhibit 1.1 too. But these are all voluntary and more importantly domestic.

8.4 ANALYSIS OF IMPACTS ON TECHNOLOGICAL INNOVATION

No analysis of technological innovation was attempted at this time. However, on examining the regulatory requirements, actions induced by the hazard levels that are set under the regulation are likely to encourage innovation. Since the hazard levels may be used by states and localities as required levels of abatement, a larger lead testing and abatement market is likely to be created. This could then lead to greater competition and development of innovative testing or abatement methods.

By setting numerical hazard levels, the type of innovation is limited to methods that allow abatement to below the standard and testing methods that can quantitatively detect levels down to the identified hazard level.

8.5 EQUITY IMPACTS ANALYSIS

The Agency is concerned about whether there are disproportionate burdens on particular categories of households or individuals as a result of its actions. Although the Section 403 hazard levels in lead-based paint, soil and dust have not yet been established this analysis investigates the equity impacts of four potential hazard levels. The hazard levels are:

- XRF $\geq$ 6 mg/cm^2 (maximum X-ray fluorescence reading in the housing unit).
- Both XRF $\geq$ 6 mg/cm^2 AND at least 10 per cent of the painted surface area is damaged.
- Dust lead concentration $\geq$ 500 ppm.
- Soil lead concentration $\geq$ 500 ppm.

Lead hazards as defined above can occur in virtually all segments of the American housing stock. However, even though lead-based paint hazards are widespread throughout the United States, and affect every socioeconomic group, the distribution of the hazards is not uniform with respect to region of the country, age of housing stock, race or household income. Lead hazards are more common in older, low-cost housing units in the North-East and Mid-West than in other units. Because these housing units tend to be occupied by households at or below the poverty level, including a disproportionate share of African-Americans, these sub-populations are potentially exposed to relatively more risks than other sub-populations. To the extent that

Section 403 results in more abatement of hazards in housing (including paint, dust and soil abatement), the segments of the U.S. population that are disproportionately exposed to the hazards are likely to receive a larger share of the risk reductions. However, because most of the abatements covered by Title IV are voluntary, relatively wealthier households are more likely to proceed with the risk-reducing abatements. This section of the report describes the distribution of lead-based paint hazards in the housing stock, and considers the environmental equity implications of that distribution.

The distributions, in the U.S. housing stock, of the four potential hazard conditions listed above are estimated using data from the national survey of lead-based paint in housing sponsored by the U.S. Department of Housing and Urban Development (HUD). The HUD survey was a national stratified sample of 284 privately owned, occupied housing units built before 1980. HUD developed weights for each observation, to create a weighted national sample representing the 77.1 million privately owned and occupied housing units. The analysis in this section is based on the HUD estimates of the national pre-1980 housing stock. These estimates are shown in Exhibit 8-2.

EXHIBIT 8-2

National Prevalence of Lead-Based Paint Hazards

	XRF ≥ 6	XRF ≥ 6 and > 10% Bad Condition	Dust Concentration ≥ 500 ppm	Soil Concentration ≥ 500 ppm
National Prevalence in Pre-1980 Housing Stock	11%	4%	34%	11%

8.5.1 Age of Housing Stock

In general, lead-based paint hazards are more common in older housing stock. Even though lead was not banned in household paint until 1978, the lead content of paint declined after World War II. This is reflected in the distribution of the age of the housing stock that has a lead-based paint hazard as shown in Exhibit 8-3. For example, 61 percent of the housing stock with a maximum XRF reading of 6 mg/cm^2 or more was built before 1930, even though only 21 percent of the existing stock of pre-1980 housing units is that old. Shading indicates a disproportionate prevalence of a potential hazard (i.e., the actual prevalence of a hazard in a sub-group is at least 5 percent more than the sub-groups' share of the total national housing stock). It is important to realize that even though the older units are more likely to have a paint hazard, hazards do exist in some housing units of all ages.

EXHIBIT 8-3

Distribution of Age of Housing Unit and Lead-Based Paint Conditions

Year Built	Overall Housing Stock Distribution	XRF ≥ 6	XRF ≥ 6 and > 10% Bad Condition	Dust Concentration ≥ 500 ppm	Soil Concentration ≥ 500 ppm
Pre 1930	21%	61%	39%	43%	73%
1930 - '49	13%	14%	14%	16%	7%
1950 - '65	43%	25%	47%	23%	20%
1966 - '78	22%	-	-	19%	-
Total	*100%*	*100%*	*100%*	*100%*	*100%*

8.5.2 Regional Distribution

Because the North-East and Mid-West regions of the country tend to have relatively more older housing units than the South and West, these regions would be expected to have more paint hazards than regions with newer housing stock. However, the hazards are even greater than would be expected if only housing age was considered. For example, of the national housing stock with maximum XRF readings of 6 mg/cm^2 or more, 57 percent occur in the North-East region. Further, a total of 77 percent occur in the combined North-East and Mid-West regions; whereas these two regions have only 47 percent of the total pre-1980 housing stock. In contrast, the HUD survey found that in the West, which has 19 percent of the total housing stock, high XRF readings occur in only 4% of all housing. Exhibit 8-4 shows the regional distribution of the four lead-based paint hazards.

EXHIBIT 8-4

Regional Distribution of Lead-Based Paint Conditions

Region	Overall Housing Stock Distribution	XRF ≥ 6	XRF ≥ 6 and > 10% Bad Condition	Dust Concentration ≥ 500 ppm	Soil Concentration ≥ 500 ppm
Mid West	25%	20%	35%	30%	55%
North-East	22%	57%	49%	31%	13%
South	34%	19%	17%	27%	17%
West	19%	4%	-	12%	15%
Total	*100%*	*100%*	*100%*	*100%*	*100%*

8.5.3 Cost of Housing

The equity effects of uneven regional and housing age distribution of the four hazards are compounded by an uneven distribution of various demographic and socioeconomic sub-populations. Although some of the nation's older housing stock is premium real estate, and commands a high market price, in general older housing units are less expensive than newer units. Thus, the higher prevalence of the four hazards in the older housing stock is related to the fact that people living in lower cost housing are disproportionately exposed to the lead-based paint hazards. The prevalence of the four hazards by monthly housing cost (measured as either monthly rent or monthly mortgage payment to amortize a 10 percent mortgage in 30 years, not including taxes or insurance) is shown on Exhibit 8-5. The least expensive housing (less than $250 per month) has a disproportionately higher share of each of the four hazards than more expensive housing.

Notice that the problem is not confined to low-cost housing. Even the most expensive housing units have some prevalence of hazards, and comprise a disproportionately higher share of all units with high XRF readings.

EXHIBIT 8-5

Distribution of Monthly Housing Costs and Lead-Based Paint Hazards

Monthly Housing Cost	Overall Housing Stock Distribution	XRF ≥ 6	XRF ≥ 6 and > 10% Bad Condition	Dust Concentration ≥ 500 ppm	Soil Concentration ≥ 500 ppm
< $250	17%	35%	53%	24%	32%
$250-$500	29%	26%	8%	22%	24%
$500-$750	18%	13%	32%	15%	23%
$750-1500	20%	2%	-	21%	14%
> $1500	16%	24%	7%	18%	7%
Total	*100%*	*100%*	*100%*	*100%*	*100%*

8.5.4 Income

As would be expected, the relationship of lead-based paint hazards and income reflects that poorer people tend to live in the lower-cost houses, and thus bear a disproportionate share of the exposure to the four hazards. Exhibit 8-6 shows the distribution of household income and the hazards and that while the poorest people are far more likely to live in housing with a paint hazard, the hazards also occur for higher income households.

EXHIBIT 8-6

Distribution of Household Annual Income and Lead-Based Paint Conditions

Household Annual Income	Overall Housing Stock Distribution	XRF ≥ 6	XRF ≥ 6 and > 10% Bad Condition	Dust Concentration ≥ 500 ppm	Soil Concentration ≥ 500 ppm
< $10k	19%	42%	52%	28%	19%
$10 - 20k	16%	9%	4%	12%	9%
$20 - 30k	18%	16%	24%	12%	24%
> $30k	40%	27%	20%	45%	43%
NA	6%	5%	-	3%	5%
Total	*100%*	*100%*	*100%*	*100%*	*100%*

8.5.5 Affordability

The regulatory impact analysis has considered abatement decision rules where each household chooses the type of abatement that maximizes its net benefits (both social and private benefits e.g., damages avoided by future children born into the current householders' abated house are included as well as the damages avoided by the householders' children). No consideration has been made of whether the household could afford its optimal abatement choice. The following analysis compares an affordability threshold based on household income to the costs of the abatements chosen under the decision rules developed in this report. The issues raised for public financing of abatements are also discussed.

Affordability Measure and Income

Affordability measures are typically based on either income or the value of the asset being improved. For this analysis, we chose an income measure because of the short time (seven years) over which the benefit is accrued and the availability of data. In the past, the Agency has used a range of affordability measures. Typical measures for large scale capital projects are 1.8-2.1 percent of median household income in perpetuity (U.S. EPA, 1990). However, the case considered in this report is different because the benefits to a householders' child (and thus the duration of payment) occur over seven years. Therefore, we assumed that householders would be willing to spend as much as (5%) of their income annually if the duration were limited to seven years. The long term cost of capital, seven percent, is used as the discount rate.

The distribution of household incomes from the Housing and Urban Development (HUD) study (Exhibit 8-6) served as the basis for this analysis. Two modifications were made to the distribution; first the home owners who had not reported incomes were redistributed in the same proportions as those who had reported, and second, the "greater than $30,000" income category was divided into two ranges of equal frequency (those between $30,000 and $50,000, and those greater than $50,000). Because $30,000 was the median income in 1990, the 75th percentile income, $50,000, was chosen as the range limit (U.S. Department of Commerce, 1992). The resulting household income distribution is shown in Exhibit 8-7.

EXHIBIT 8-7

Household Income Distribution and Affordability Threshold

Household Annual Income	Overall Housing Stock Distribution	Affordability Threshold
< $10k	21%	$1,442
$10 - <20k	17%	$4,325
$20 - <30k	19%	$7,208
≥30k - <50k	21.5%	$8,650
≥50k	21.5%	$14,416

Exhibit 8-7 also shows the affordable price (or threshold) associated with each income level; households are assumed to pay no more than the affordability threshold for an abatement. The affordable abatement cost was calculated from the midpoints of the income ranges except in the final two categories where the lower limits of the category ($30,000 and $50,000) were used. By using an affordability measure based on income, two further assumptions have been made implicitly. First, we assume owners pay the cost of abatement and generate no increase in property value as a result, and second, we assume that the cost of abatement is passed directly to renters. If property values increase as a result of abatement, we have underestimated the number of affordable abatements. Exhibit 8-8 compares the abatement costs, described in detail in Chapter 4, to the affordability thresholds. Note that only nonrecurrent dust abatement is affordable at all income levels and only 18 of the 95 income/abatement combinations are affordable.

EXHIBIT 8-8

Affordable Abatement Scenarios by Income Level for Five Percent of Income

Abatement Scenario	Abatement Unit Cost	Income	<$10K	$10->$20K	$20->$30K	$30->$50K	>$50K
		Affordability	$1,442	$4,325	$7,208	$8,650	$14,416
High-end Paint	$10,500						x
Low-end Paint	$2,750			x	x	x	x
High-end Soil							
>2000 ppm and exterior paint	$21,412						
≤2000 ppm and exterior paint	$12,998						
>2000 ppm and no exterior paint	$16,412						
≤2000 ppm and no exterior paint	$7,998					x	x
Low-end Soil	$7,493					x	x
Recurrent Dust	$7,676					x	x
Nonrecurrent Dust	$750		x	x	x	x	x
High-end Paint and High-end Soil							
>2000 ppm and exterior paint	$31,912						
≤2000 ppm and exterior paint	$23,498						
>2000 ppm and no exterior paint	$26,912						
≤2000 ppm and no exterior paint	$18,498						
High-end Paint and Low-end Soil	$17,993						
Low-end Paint and High-end Soil							
>2000 ppm and exterior paint	$24,162						
≤2000 ppm and exterior paint	$15,748						
>2000 ppm and no exterior paint	$19,162						
≤2000 ppm and no exterior paint	$10,748						x
Low-end Paint and Low-end Soil	$10,243						x

Results

Exhibit 8-9 shows the number of affordable abatements by scenario and decision rule over the fifty year model lifetime. (The nine decision rules were explained in Chapter 6.) As explained in Chapter 3, each abatement decision represents a portion of the housing stock. To determine the number of unaffordable abatements we compared the five affordability thresholds in proportion to their frequency in the housing stock distribution (as shown in Exhibit 8-7) to the cost of the abatement chosen. Those abatements costing more than the affordability threshold were considered unaffordable.

The percent of optimal abatements that are affordable range from over 99 percent in the voluntary optimum decision rule to 43 percent for rules where doing only non-recurrent dust abatement, the most affordable scenario, does not satisfy the decision rule constraints. The affordability by abatement type (in Exhibit 8-9) shows where the majority of the unaffordable abatements are for each decision rule. The constraint of abating all nonintact paint combined with the relatively high cost of paint abatement causes these categories (high-end paint, low-end paint, high-end paint and high-end soil, low-end paint and low-end soil, and low-end paint and high-end soil) to account for the majority of the unaffordable abatements.

For every decision rule but the voluntary optimum, the total net benefits of the affordable abatements are higher than the total net benefits of all abatements. This means that for all decision rules other than the voluntary optimum, many of those who could not afford to abate had individual negative net benefits. For example, the total net benefit for a decision rule based on 1,200 ppm dust are $3.3 billion when affordability is ignored. Once affordability thresholds are imposed, the net benefits rise to $15.6 billion. In the voluntary optimum, however, individual benefits always exceed individual costs. Thus, eliminating any households because they cannot afford to abate will reduce the net benefits.

From a social welfare perspective, only those homes with positive net benefits warrant abatement. Those households who cannot afford to abate may be publicly funded. The following discussion characterizes the number and value of the abatements that would qualify for assistance under this perspective. First, Exhibit 8-10 shows the number of unaffordable abatements which have positive net benefits, the majority of which are low soil abatements. The total net benefits correspondingly range from $454 to $680 million or about $33 million to $49 million annually at a seven percent discount rate. The total cost, over the fifty year model lifetime, of subsidizing these abatements ranges from $622 million for the paint condition only to almost $2 billion for the three media constrained decision rule. This translates into approximately $45 million to $145 million annually.[1]

If all the unaffordable abatements were funded, whether they result in positive net benefits or not, the cost range would be $1.1 billion to $20.8 billion, which is equivalent to $80

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[1] The numbers presented represent an upper bound by subsidizing the total cost of the abatement. If each household paid to its affordability threshold, the total cost over 50 years would range from $387 million to $1.3 billion. This translates into $28 million to $94 million annually.

million to $1.5 billion annually.[2] However, the range of net benefits would fall significantly. The new range is minus $12.7 billion to positive $454 million, which, on an annual basis, is minus $920 million to positive $33 million.

Note that this analysis only considers the affordability of the optimal abatement chosen based on maximizing net benefits. A more in-depth analysis could introduce an affordability constraint when the optimal abatement is being chosen, limiting the abatement choices to those below an affordability threshold. This would decrease the total benefits but could also reduce costs. Finally, the cost of testing for lead has not been included. These costs can be substantial, $713 per unit, if all media are tested. Obviously, the number of unaffordable abatements would increase if the testing costs were added.

Funding for lead abatements (including inspection) is formalized and authorized at $125 million for 1993 and $250 million for 1994 according to Title X, Section 1011. Additional funds may be available through subsequent Appropriations Acts. This level of funding compares favorably with the amount needed to subsidize unaffordable abatements that result in positive net benefits. However, the funding may not be adequate to subsidize all unaffordable abatements induced by certain decision rules. Further, the funding is only appropriated over two years and the model project lifetime is fifty years. (Thus the same level of funding would have to be appropriated each year for the next fifty years.) The case presented here does not consider all the possible sources of funds for residential lead abatement. States and localities have a history of funding such projects. It may be possible to extend the funds by providing concessionary loans as Massachusetts has done. In this way, abatements can be performed on loans at subsidized interest rates but at a lower cost to government than a grant program. The case presented here represents an upper bound estimate of the annual cost to government of subsidizing abatements.

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2 These values represent the upper bound by subsidizing the total cost of the abatement. The total cost over 50 years would range from $780 million to $12.7 billion equivalent to $56 million to $920 million annually if each household paid an amount equal to its affordability value.

EXHIBIT 8-9

Affordability (at Five Percent of Income) of Abatement Choices for Five Alternative Decision Rules

Decision Rules		Soil (ppm)	Dust (ppm)	Paint (XRF, mg/cm²)	Nonintact Paint Abatement Recommended	Total Net Benefits Exclusive of Testing Costs ($ millions)	Total Affordable Abatements (1000s) (Percent of Total)	Total Net Benefits of Affordable Abatements Exclusive of Testing Costs ($ millions)	Number and Percent of Total Homeowners with Unaffordable Abatements by Type [a] (1000s)									
									HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NRD
1. Voluntary Optimum		-	-	-	No	34,294	44,832 99.26%	33,840		4 0.01%		329 0.73%						0 0%
2. Paint Condition Only		-	-	-	Yes	-17,349	3,089 43.74%	-4,834	3,265 46%	583 8%					114 2%		12 0.17%	
3. Single Medium Plus Condition	3a.	2,300	-	-	Yes	-17,159	3,488 43.23%	-4,711	3,265 40%	570 7%		573 7%			114 1%		58 1%	
	3b.	-	1,200	-	Yes	3,299	11,169 71.59%	15,635	3,286 21%	573 4%	42 0.27%	234 2%	158 1%		114 1%	14 0.09%	12 0.08%	0 0%
	3c.	-	-	20	Yes	-17,631	3,134 43.75%	-4,921	3,313 46%	591 8%	0				114 2%		12 0.17%	
4. 2-Media Plus Condition	4a.	2,300	1,200	-	Yes	3,017	11,391 70.33%	15,554	3,286 20%	561 3%	42 0.26%	573 4%	158 1%		114 1%	14 0.09%	58 0.36%	0 0%
	4b.	2,300	-	20	Yes	-17,440	3,533 43.24%	-4,798	3,313 41%	579 7%		573 7%			114 1%		58 0.71%	
	4c.	-	1,200	20	Yes	3,017	11,213 71.41%	15,548	3,334 21%	582 4%	42 0.27%	234 1.49%	158 1%		114 1%	14 0.09%	12 0.08%	0 0%
5. 3-Media Plus Condition		2,300	1,200	20	Yes	2,736	11,435 70.17%	15,468	3,334 20%	570 3%	42 0.26%	573 4%	158 1%		114 1%	14 0.08%	58 0.36%	0 0%

[a] Abatement Codes: High Paint(HP); Low Paint(LP); High Soil(HS); Low Soil(LS); Recurrent Dust (RD); High Paint and High Soil(HP/HS); High Paint and Low Soil(HP/LS); Low Paint and High Soil (LP/HS); Low Paint and Low Soil (LP/LS); Nonrecurrent Dust (NRD). The abatement activities were described in Exhibits 4.1-4.6.

EXHIBIT 8-10

Affordability (at Five Percent of Income) of Abatement Choices for Households with Positive Net Benefits for Five Alternative Decision Rules

Decision Rules		Soil (ppm)	Dust (ppm)	Paint (XRF, mg/cm²)	Nonintact Paint Abatement Recommended	Total Net Benefits of Unaffordable Abatements with Positive Net Benefits Exclusive of Testing Costs ($ millions)	Total Costs of Unaffordable Abatements with Positive Net Benefits Exclusive of Testing Costs ($ millions)	Total Costs of Unaffordable Abatements ($ million)	Number and Percent of Total Homeowners with Unaffordable Abatements by Type[a] (1000s)									
									HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NRD
1. Voluntary Optimum		-	-	-	No	454	1,141	1,141		4 0.01%		329 0.73%						0 0%
2. Paint Condition Only		-	-	-	Yes	226	622	17,545	104 1.47%	48 0.69%					0 0%		12 0.17%	
3. Single Medium Plus Condition	3a.	2,300	-	-	Yes	642	1,679	19,726	104 1.29%	48 0.60%		306 4%			0 0%		12 0.15%	
	3b.	-	1,200	-	Yes	532	1,728	19,223	104 0.67%	43 0.27%	42 0.27%	234 1.50%	42 0.27%		0 0%	0 0%	12 0.08%	0 0%
	3c.	-	-	20	Yes	226	622	17,787	104 1.45%	48 0.68%					0 0%		12 0.17%	
4. 2-Media Plus Condition	4a.	2,300	1,200	-	Yes	680	1,976	20,595	104 0.64%	43 0.26%	42 0.26%	306 1.89%	42 0.26%		0 0%	0 0%	12 0.08%	0 0%
	4b.	2,300	-	20	Yes	642	1,679	19,968	104 1.27%	48 0.59%		306 3.75%			0 0%		12 0.15%	
	4c.	-	1,200	20	Yes	532	1,728	19,464	104 0.66%	43 0.27%	42 0.27%	234 1.49%	42 0.27%		0 0%	0 0%	12 0.08%	0 0%
5. 3-Media Plus Condition		2,300	1,200	20	Yes	680	1,976	20,837	104 0.64%	43 0.26%	42 0.26%	306 1.88%	42 0.26%		0 0%	0 0%	12 0.08%	0 0%

[a]Abatement Codes: High Paint(HP); Low Paint(LP); High Soil(HS); Low Soil(LS); Recurrent Dust (RD); High Paint and High Soil(HP/HS); High Paint and Low Soil(HP/LS); Low Paint and High Soil (LP/HS); Low Paint and Low Soil (LP/LS); Nonrecurrent Dust (NRD). The abatement activities were described in Exhibits 4.1-4.6.

Alternative Threshold Analysis

Exhibit 8-11 shows which abatements are affordable if two percent of income over seven years is used as the affordability threshold. The two percent level corresponds to past EPA analysis although the period, seven years, is shorter as described above (U.S.EPA, 1990). Only seven of the 95 income/abatement combinations are affordable. As expected, the percent of affordable abatements decreases for each decision rule when compared to the five percent affordability threshold. (See Exhibit 8-12.) Only 78 percent of the abatements are affordable under the voluntary optimum; this falls to less than 25 percent for decision rules where nonrecurrent dust abatement is not an option. Exhibit 8-13 shows that the total cost over fifty years of subsidizing all households below the threshold which have positive individual net benefits is $825 million to $4.4 billion or $60 to $319 million annually discounted at seven percent. Corresponding net benefits are $334 million to $7.8 billion or $24 to $565 million annually. This alternative analysis shows the importance of the affordability threshold chosen to the quantity of abatements that are considered unaffordable.

EXHIBIT 8-11
Affordable Abatement Scenarios by Income Level for Two Percent of Income

		Income	<$10K	$10->$20K	$20->$30K	$30->$50K	>$50K
		Affordability Threshold	$577	$1,730	$2,883	$3,460	$5,767
Abatement Scenario	Abatement Unit Cost						
High-end Paint	$10,500						
Low-end Paint	$2,750				x	x	x
High-end Soil							
>2000 ppm and exterior paint	$21,412						
≤2000 ppm and exterior paint	$12,998						
>2000 ppm and no exterior paint	$16,412						
≤2000 ppm and no exterior paint	$7,998						
Low-end Soil	$7,493						
Recurrent Dust	$7,676						
Nonrecurrent Dust	$750			x	x	x	x
High-end Paint and High-end Soil							
>2000 ppm and exterior paint	$31,912						
≤2000 ppm and exterior paint	$23,498						
>2000 ppm and no exterior paint	$26,912						
≤2000 ppm and no exterior paint	$18,498						
High-end Paint and Low-end Soil	$17,993						
Low-end Paint and High-end Soil							
>2000 ppm and exterior paint	$24,162						
≤2000 ppm and exterior paint	$15,748						
>2000 ppm and no exterior paint	$19,162						
≤2000 ppm and no exterior paint	$10,748						
Low-end Paint and Low-end Soil	$10,243						

EXHIBIT 8-12

Affordability (at Two Percent of Income) of Abatement Choices for Five Alternative Decision Rules

Decision Rules		Soil (ppm)	Dust (ppm)	Paint (XRF, mg/cm²)	Nonintact Paint Abatement Recommended	Total Net Benefits Exclusive of Testing Costs ($ millions)	Total Affordable Abatements (1000s) (Percent of Total)	Total Net Benefits of Affordable Abatements Exclusive of Testing Costs ($ millions)	Number and Percent of Total Homeowners with Unaffordable Abatements by Type[a] (1000s)									
									HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NRD
1. Voluntary Optimum		-	-	-	No	34,294	35,221 77.98%	26,463		8 0.02%		577 1.28%						9,359 20.72%
2. Paint Condition Only		-	-	-	Yes	-17,349	1,720 24.35%	-1,278	4,160 59%	1,054 15%					114 2%		16 0.22%	
3. Single Medium Plus Condition	3a.	2,300	-	-	Yes	-17,159	1,684 20.87%	-1,248	4,160 52%	1,032 13%		1,006 12%			114 1%		74 1%	
	3b	-	1,200	-	Yes	3,299	7,837 50.23%	14,767	4,186 27%	1,038 7%	74 0.47%	411 3%	276 2%		114 1%	18 0.11%	16 0.10%	1,633 10.47%
	3c.	-	-	20	Yes	-17,631	1,745 24 35%	-1,306	4,221 59%	1,069 15%	0				114 2%		16 0.22%	
4. 2-Media Plus Condition	4a.	2,300	1,200	-	Yes	3,017	7,801 48.16%	14,797	4,186 26%	1,015 6%	74 0.46%	1,006 6%	276 2%		114 1%	18 0.11%	74 0.46%	1,633 10.08%
	4b.	2,300	-	20	Yes	-17,440	1,708 20.91%	-1,276	4,221 52%	1,047 13%		1,006 12%			114 1%		74 0.91%	
	4c.	-	1,200	20	Yes	3,017	7,862 50.07%	14,739	4,247 27%	1,053 7%	74 0.47%	411 2.62%	276 2%		114 1%	18 0.11%	16 0.10%	1,633 10.40%
5. 3-Media Plus Condition		2,300	1,200	20	Yes	2,736	7,825 48.02%	14,769	4,247 26%	1,031 6%	74 0.45%	1,006 6%	276 2%		114 1%	18 0.11%	74 0.46%	1,633 10.02%

[a]Abatement Codes: High Paint(HP); Low Paint(LP); High Soil(HS); Low Soil(LS); Recurrent Dust (RD); High Paint and High Soil(HP/HS); High Paint and Low Soil(HP/LS); Low Paint and High Soil (LP/HS); Low Paint and Low Soil (LP/LS); Nonrecurrent Dust (NRD). The abatement activities were described in Exhibits 4.1-4.6.

EXHIBIT 8-13

Affordability (at Two Percent of Income) of Abatement Choices for Households with Positive Net Benefits for Five Alternative Decision Rules

Decision Rules		Soil (ppm)	Dust (ppm)	Paint (XRF, mg/cm^2)	Nonintact Paint Abatement Recommended	Total Net Benefits of Unaffordable Abatements with Positive Net Benefits Exclusive of Testing Costs ($ millions)	Total Costs of Unaffordable Abatements with Positive Net Benefits Exclusive of Testing Costs ($ millions)	Total Costs of Unaffordable Abatements Threshold ($ million)	Number and Percent of Total Homeowners with Unaffordable Abatements by Type[a] (1000s)									
									HP	LP	HS	LS	RD	HP/HS	HP/LS	LP/HS	LP/LS	NRD
1. Voluntary Optimum		-	-	-	No	7,831	4,496	4,496		8 0.02%		577 1.28%						9,359 21%
2. Paint Condition Only		-	-	-	Yes	334	825	22,487	132 1.87%	88 1.24%					0 0%		16 0.22%	
3. Single Medium Plus Condition	3a.	2,300	-	-	Yes	1,065	2,680	26,210	132 1.64%	88 1.09%		537 6.65%			0 0%		16 0.19%	
	3b.	-	1,200	-	Yes	5,141	3,203	25,801	132 0.85%	77 0.50%	74 0.47%	411 2.63%	74 0.47%		0 0%	0 0%	16 0.10%	1,591 10%
	3c.	-	-	20	Yes	334	825	22,801	132 0.00%	88 0.00%					0 0%		16 0.22%	
4. 2-Media Plus Condition	4a.	2,300	1,200	-	Yes	5,401	3,638	28,104	132 0.82%	77 0.48%	74 0.46%	537 3.32%	74 0.46%		0 0%	0 0%	16 0.10%	1,591 10%
	4b.	2,300	-	20	Yes	1,065	2,680	26,524	132 1.62%	88 1.07%		537 6.57%			0 0%		16 0.19%	
	4c.	-	1,200	20	Yes	5,141	3,203	26,115	132 0.84%	77 0.49%	74 0.47%	411 2.62%	74 0.47%		0 0%	0 0%	16 0.10%	1,591 10%
5. 3-Media Plus Condition		2,300	1,200	20	Yes	5,401	3,638	28,418	132 0.81%	77 0.47%	74 0.45%	537 3.29%	74 0.45%		0 0%	0 0%	16 0.10%	1,591 10%

[a]Abatement Codes: High Paint(HP); Low Paint(LP); High Soil(HS); Low Soil(LS); Recurrent Dust (RD); High Paint and High Soil(HP/HS); High Paint and Low Soil(HP/LS); Low Paint and High Soil (LP/HS); Low Paint and Low Soil (LP/LS); Nonrecurrent Dust (NRD). The abatement activities were described in Exhibits 4.1-4.6.

8.5.6 Race

Lead-based paint hazards are more likely to affect African-Americans than other racial sub-populations. This is a result of both the larger African-American share of the population in the North-East and Mid-West, and of the higher poverty rate for African-Americans. Exhibit 8-14 shows the distribution of the hazards by race. (Race is defined as the stated race of the youngest person in the household.)

EXHIBIT 8-14

Distribution of Household Racial Composition and Lead-Based Paint Conditions

Race	Overall Housing Stock Distribution	XRF ≥ 6	XRF ≥ 6 and > 10% Bad Condition	Dust Concentration ≥ 500 ppm	Soil Concentration ≥ 500 ppm
African-American	9%	29%	52%	14%	11%
Hispanic	7%	3%	4%	4%	3%
White	78%	66%	44%	71%	79%
Other	7%	2%	-	11%	7%
Total	*100%*	*100%*	*100%*	*100%*	*100%*

8.5.7 Other Socioeconomic Variables

The prevalence of lead-based paint hazards based on other socioeconomic variables does not show as dramatic a disproportionate prevalence as the region, income and race variables. Exhibit 8-15 shows the prevalence for the following variables: ownership, presence of children, presence of elderly. A summary of this disproportionality is as follows:

- Ownership: rental units are somewhat more likely to have high XRF readings.
- Presence of children (6 years old or less): there is no disproportionate prevalence of lead-based paint hazards among units with young children.
- Elderly (defined as at least one person over the age of 65 living in the unit): no overall pattern of disproportionate prevalence, but units including elderly people are somewhat less likely to have both high XRF readings and bad paint conditions.

EXHIBIT 8-15

Distribution of Other Household Demographic Characteristics and Lead-Based Paint Conditions

	Overall Housing Stock Distribution	XRF ≥ 6	XRF ≥ 6 and > 10% Bad Condition	Dust Concentration ≥ 500 ppm	Soil Concentration ≥ 500 ppm
Ownership					
Rent	35%	45%	41%	31%	36%
Own	65%	55%	59%	69%	64%
Children ≤ 6 Years Present?					
No	82%	79%	86%	85%	78%
Yes	18%	21%	14%	15%	22%
Adult ≥ 65 Years Present?					
No	76%	77%	100%	78%	80%
Yes	24%	23%	-	22%	20%

8.5.8 Data Limitations

The U.S. Housing and Urban Development survey provides the best nationwide data for correlating socioeconomic information and residential housing lead levels. However, the data are limited. Because only 284 privately owned homes were sampled the actual number of homes in the various socioeconomic strata of interest is small. The confidence intervals are thus correspondingly large. While the data may show trends, the small sample size indicates caution should be used in interpreting the results.

8.5.9 Environmental Equity Conclusions

Existing lead-based paint hazards are a risk to all segments of our population living in pre-1980 housing, and local, state and federal efforts to reduce the risks of lead-based paint must extend to all potentially affected parties. However, the HUD survey does indicate that some segments of our society are at relatively greater risk than others. In particular, the residents of older, low cost housing are exposed to a disproportionately greater share of lead potential hazard than other housing units. The housing stock in the North-East (and to some extent the Mid-West) includes a larger share of such units than other regions, creating a regional inequity in the prevalence of the problem. Because poorer people usually occupy low-cost housing, the hazards disproportionately fall on lower income sub-populations (especially households living in poverty, with annual incomes below $10,000), creating an income inequity. Finally, the relatively larger share of African-Americans in the lower income groups results in racial inequity.

Although the baseline risks from lead-based paint disproportionately fall on poorer sub-populations, abatement may well be more likely to occur in housing units occupied by wealthier households. Most of the abatements under the Lead-Based Paint Hazard Reduction Act will be voluntary, and wealthier households are more likely to have the means to abate an existing problem in their home, or avoid moving into a housing unit with a known lead-based paint hazard. Thus even though a national strategy of eliminating lead-based paint risks targets a problem affecting a greater share of poor households and African-Americans, the impact of income on the ability to undertake voluntary abatements may result in a more inequitable distribution of the risks in the future.

As shown in Section 8.5.5 the ability to afford abatements may have a serious impact on the number of abatements undertaken voluntarily. In addition, when the affordable abatements are considered alone the net benefits rise in all but the voluntary optimum decision rule. This implies that not all unaffordable abatements may be worth subsidizing because some have negative net benefits. However, subsidizing only those with positive net benefits raises a fairness issue, since many of the affordable abatements induced by the decision rule had negative net benefits yet presumably were paid for privately by households. Should those who cannot afford abatements be given the same treatment? In practice, can the homes with positive and negative net benefits be identified in a cost effective manner? Finally, significant funds, sustained over time, will be required to subsidize even those unaffordable abatements which have net benefits greater than zero.

8.6 REFERENCES

U.S. Environmental Protection Agency, 1990. (U.S. EPA, 1990) "National Characterization of Small Communities: The Ability to Finance Wastewater Construction Projects", April.

U.S. Department of Commerce, 1992. (U.S. Department of Commerce, 1992) "Statistical Abstract of the United States, 1992" U. S Government Printing Office.