COMPARATIVE BENEFITS ANALYSIS
PROJECT XLC: COLUMBUS, OHIO

prepared by

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1 August 2000

Forward

This Comparative Benefits Analysis was prepared by the National Center for Environmental Assessment, RTP Office (NCEA-RTP) in support of the Office of Reinvention's Project XLC Program. Project XLC (eXcellence and Leadership for Communities) encourages environmental excellence and leadership within the regulated community and allows an organization to pursue an innovative program that might achieve better results that what would be achieved under current regulatory requirements.

This is the first Project XLC proposal involving the comparative benefits for lead that has reached the Final Project Agreement stage. There are no clear guidelines for the preparation of a Comparative Benefits Analysis, but it is obvious that the intent of this provision was to show that the proposed innovative program must demonstrate a clear environmental benefit when compared to the expected impact of the current regulatory requirement. Consequently, this report takes the approach of a comparative risk reduction by contrasting the expected change in risk from the hypothetical removal of lead service lines under the current regulatory requirements to the expected change in risk under the proposed lead-based paint intervention program. The reader should be aware that the removal of lead service lines is only hypothetical and might not occur under the existing regulatory requirements. Likewise, the lead-based paint intervention program is currently in existence but, without the XLC program, faces funding uncertainties that make predictions of benefits highly speculative.

This Comparative Benefits Analysis has been reviewed by members of the Columbus XLC Project team representing AO, OW, Region 5, OGC, and ORD-NERL/CIN, and by staff members of NCEA-RTP.

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The City of Columbus, OH has submitted a Project XLC proposal through which they plan to expand their Lead-Safe Columbus Program (LSCP) while seeking flexibility in compliance with the Lead and Copper Rule (LCR) (City of Columbus Division of Water, 1999). Project XLC acceptance criteria require the demonstration of superior environmental performance at two tiers: 1) the project must provide equivalent public health compliance with the LCR; and 2) the project must go beyond providing equivalent public health protection to achieve superior environmental performance. In the negotiations to date, US EPA has qualitatively accepted the demonstration of the potential to achieve superior environmental performance, and now proposes to evaluate the project quantitatively prior to project implementation. The basis for this quantitative evaluation is the Comparative Benefits Analysis, which is the subject of this report.

The basis of this analysis is the Project XLC proposal submitted by the City of Columbus Division of Water, dated June 11, 1999. Additional information was received through conversations with representatives of the Columbus Childhood Lead Poisoning Prevention Program, the City of Columbus Health Department, who co-sponsored the Project XLC proposal with the City of Columbus Division of Water, and the Ohio EPA.

The components of this comparative benefits analysis are comparable to the standard US EPA assessment tools: risk assessment, risk management, and risk communication. Lead is the hazard of interest. The primary issue with respect to the LCR is that lead service lines may, as a result of changes in water chemistry, need to be replaced if sampling at the residences indicates that the water chemistry changes have caused an unacceptable increase in lead concentration. If the increased risk from exposure to these lead service lines is low or non-existent, compared to the risk reduction that could be achieved through the LSCP, then this would be the basis of the Comparative Benefits analysis.

In this analysis, it is assumed that: 1) some children will receive the benefits of the LSCP who would not have been impacted by lead service lines ; 2) some children will be negatively impacted by lead service lines, and will not receive the benefits of the LSCP; 3) some children will receive the benefits of the LSCP, but will also be exposed to possible effects of lead service lines. It is also likely that many children in Columbus will not be impacted by either the lead service lines or the LSCP.

At this point it is important to recognize that the City of Columbus has no evidence that their proposed changes in the water chemistry will cause any increase in the lead released from lead service lines, but propose to verify this finding with further sampling and testing. This report assumes the impact would be large enough to trigger the sampling and replacement provisions of the LCR. On the other hand, participants in the LSCP during the period 1995-97 experienced a substantial reduction in lead exposure, as reflected in the sizeable decrease in blood lead concentrations for a large number (97.5%) of the children with follow up blood measurements. The process described herein is an objective look at several scenarios under which possible lead exposure might be increased or decreased by the proposed actions.

Exposure scenarios used for the development of hypothetical risk assessments

The initial step in the risk assessment is an exposure assessment, which involves the development of several comparable exposure scenarios. The most susceptible targets for lead exposure are children six years old and younger, and women of child-bearing age[1]. Young children are particularly vulnerable because their developing nervous system can be adversely affected at relatively low levels of lead exposure. Exposure conditions that are protective for young children are also protective for women of child bearing age, except in the case of substantial adult occupational exposure, and these childhood exposure analyses are the basis of this risk assessment.

The exposure scenarios used in this analysis account for exposure to Pb from all routes. The routes of exposure are: inhalation of air, and the ingestion of food, drinking water, and dust. Dermal absorption of lead from dust is believed to be an insignificant source of lead, due to the protective barrier of the skin and the chemical form of the lead.

The amounts of Pb ingested with food and inhaled with air are held constant for all populations and all exposure scenarios, while the Pb in drinking water and dust changes with each exposure scenario. Although we are mainly interested in the comparative exposures of individual populations that vary according to their dust Pb and drinking water Pb ingestion, the baseline of lead ingested with food and inhaled with air is a critical factor in the final determination of risk, which is the fraction of the population that exceeds 10 Fg Pb/dL blood.

The calculation the total exposure for the population and the conversion of this exposure amount into an estimate of the concentration of lead in blood is accomplished through the use of the Integrated Exposure Uptake Biokinetic (IEUBK) model for lead in children, which has been the preferred risk assessment tool, at the US EPA, for lead in children since the release of the model in 1994 (U.S. Environmental Protection Agency, 1994). When using the IEUBK model, the risk assessor enters the key parameters of each exposure scenario and the model simulates the absorption of this lead and its distribution among the various significant body tissues, including blood, while accounting for the elimination of lead from the body by several routes. The growth of the child is calculated on a daily basis, and programmed changes in the corresponding ingestion rates for the exposure media are made during this calculation.

The blood lead concentration can be calculated for any designated age during the model run. These analyses assume each child is exposed from birth to 84 months. The reported value represents the net accumulation (following ingestion, distribution among body tissues, and elimination) from birth to this age. This value can be interpreted as the blood lead concentration for an individual child, or more generally, to the geometric mean of a population of children where individual exposures are similar. The generally accepted practice is to assume that children in the same neighborhood at the same age have approximately the same exposure to lead. Nevertheless,

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[1]The main concern for women of childbearing age is the storage of lead in bone tissue that can later be passed on to the developing fetus during pregnancy. Because this lead can be stored for several years, it is important to distinguish between pregnant women and women of childbearing age.

individual variability within this population would produce a distribution around this geometric mean, and this variability is expressed as a geometric standard deviation (GSD) with an accepted value of 1.6. This distribution is the basis for determining the key risk assessment parameter, the number of children at risk. The risk assessor defines the risk level, usually 10 Fg/dL for Pb in blood, and the level of protection, usually 95% of the population. The IEUBK model reports the percentage of children above the risk level. The risk assessor can then convert this to expected numbers of individuals when the size of the target population is known.

For this risk assessment, default model values are used for all parameters except dust ingestion rates, dust Pb concentration, and first draw drinking water concentrations. Information is incomplete on differences between neighborhoods that might impact other exposure factors such as diet and air Pb concentrations, so all neighborhoods are assumed to be the same in this respect, and default values for air and dietary Pb (Table 2) are used. Tables 3 and 4 show the values for drinking water, soil and dust input parameters. In Table 3, the first draw drinking water concentration is set at 15 Fg/L for those children who are selected on the assumption that, based on recent experience in Columbus OH, corrective action such as chemical treatment of the drinking water would be taken to reduce corrosion if the sampling program detects values exceeding 15 Fg/dL. Table 4 shows that dust ingestion rates are reduced by 50% where parental education has an impact (Scenario Groups 3-6), and dust concenration rates are reduced from 1200 to 200 in those cases where hazard abatement takes place (Scenario Groups 4 and 6).

Figure 1 shows the probability distribution for blood lead in a population comparable to Scenario Group 1, from age 0 to 84 months. This distribution predicts a geometric mean blood lead concentration of 3.7 Fg/dL, and also predicts that 1.6 % of the population would exceed 10 Fg/dL. This is the "control group" not impacted by either Pb service lines or Pb-based paint.

Risk Management

Risk management decisions normally focus on the actions needed to assure that 95%[2] of the target population remains below 10 Fg /dL for the age group of interest (normally children under seven years). If more than 5 % of the target population is above 10 Fg/dL, then the risk management concerns would focus on remedial actions that could most effectively bring this population below the 10 Fg/dL.

In the case of a comparative benefits analysis, the risk manager must do more than assess the risk to each population and determine that no untreated population will experience a significant increase, defined here as exceeding the 5% over the target level, and that those populations receiving treatment can expect a significant reduction in the percentages above 10 Fg/dL. The additional requirements are:

1) identify the populations to be compared;

[2] Ideally, all of the population should be below 10 Fg/dL, the level at which environmental intervention on a population basis should be initiated. Realistically, 95% is generally accepted as a reasonable public health objective for the percentage of children below 10 Fg/dL.

2) determine the expected exposure scenarios under the possible program options;
3) identify the acceptable change in exposure (e.g. increase of >2 Fg/dL, or an increase in the percent above 10 Fg/dL), and
4) develop a risk communication plan.

The populations to be compared are defined by six exposure scenarios. Table 1 shows the scheme for these exposure scenarios.

Table 1. Exposure scenario intervention scheme.

	Pb-based Paint Present	Pb Service Line Present[3]	Pb-based Paint Intervention	
			Hazard Abatement	Parental Education
Scenario Group 1	N	N	N	N
Scenario Group 2	N	Y	N	N
Scenario Group 3	Y	N	N	Y
Scenario Group 4	Y	N	Y	Y
Scenario Group 5	Y	Y	N	Y
Scenario Group 6	Y	Y	Y	Y

Risk Communication

This analysis allows us to ensure this XLC program will not significantly increase the risk for one group to lower the risk for another group. The comparative benefits analysis should be able to say that the increased risk encountered by one population is insignificant, while the reduction in risk is substantial for the second population. Tables 2, 3 and 4 show the default values for all model parameters, and all age ranges, with the key values to be varied among the exposure scenarios highlighted in bold in Table 3 and 4. The pre and post treatment model outputs for some of the exposure scenarios are shown on figures 1-6.

[3]If a Pb service line is present, this analysis assumes that 50% of the water consumed is "first draw," where the water that has been standing in the Pb service line for six hours or more.

Table 2. Default air and dietary exposure parameters in the IEUBK model.

	EXPOSURE TO AIR[4]				DIETARY EXPOSURE[4]
AGE	TIME OUTDOORS (hours)	VENTILATION RATE (m^3/day)	LUNG ABSORPTION (%)	OUTDOOR AIR Pb CONC (Fg Pb/m^3)	DIETARY INTAKE (Fg Pb/day)
0.5-1	1.00	2.00	32.00	0.10	5.53
1-2	2.00	3.00	32.00	0.10	5.78
2-3	3.00	5.00	32.00	0.10	6.49
3-4	4.00	5.00	32.00	0.10	6.24
4-5	4.00	5.00	32.00	0.10	6.01
5-6	4.00	7.00	32.00	0.10	6.34
6-7	4.00	7.00	32.00	0.10	7.00

Table 3. Drinking water exposure parameters for exposure scenarios 1-6.

DRINKING WATER EXPOSURE					
AGE	DRINKING WATER INTAKE[4] (L/day	Pb CONC FLUSHED (Fg/L)[4] (35%)	Pb CONC FOUNTAIN (Fg/L)[4] (15%)	**Pb CONC FIRST DRAW[5] (Fg/L) (50%)**	**Pb CONC FIRST DRAW[6] (Fg/L) (50%)**
0.5-1	0.20	1.00	10.00	**4.00**	**15.00**
1-2	0.50	1.00	10.00	**4.00**	**15.00**
2-3	0.52	1.00	10.00	**4.00**	**15.00**
3-4	0.53	1.00	10.00	**4.00**	**15.00**
4-5	0.55	1.00	10.00	**4.00**	**15.00**
5-6	0.58	1.00	10.00	**4.00**	**15.00**
6-7	0.59	1.00	10.00	**4.00**	**15.00**

[4] Values remain same for all scenarios

[5] Values indicate no Pb service line and apply to scenarios 1,3, and 4

[6] Values indicate Pb service line and apply to scenarios 2, 5 and 6

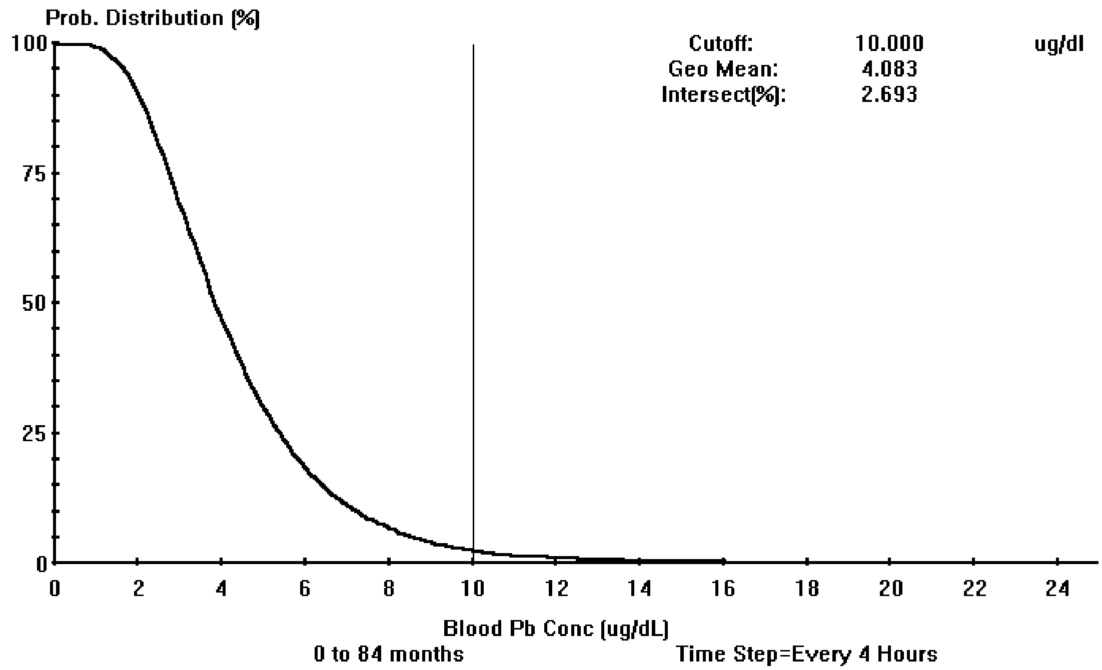

Figure 1. Pre-intervention distribution for Group 2 with first draw drinking water at 15 Fg/L.

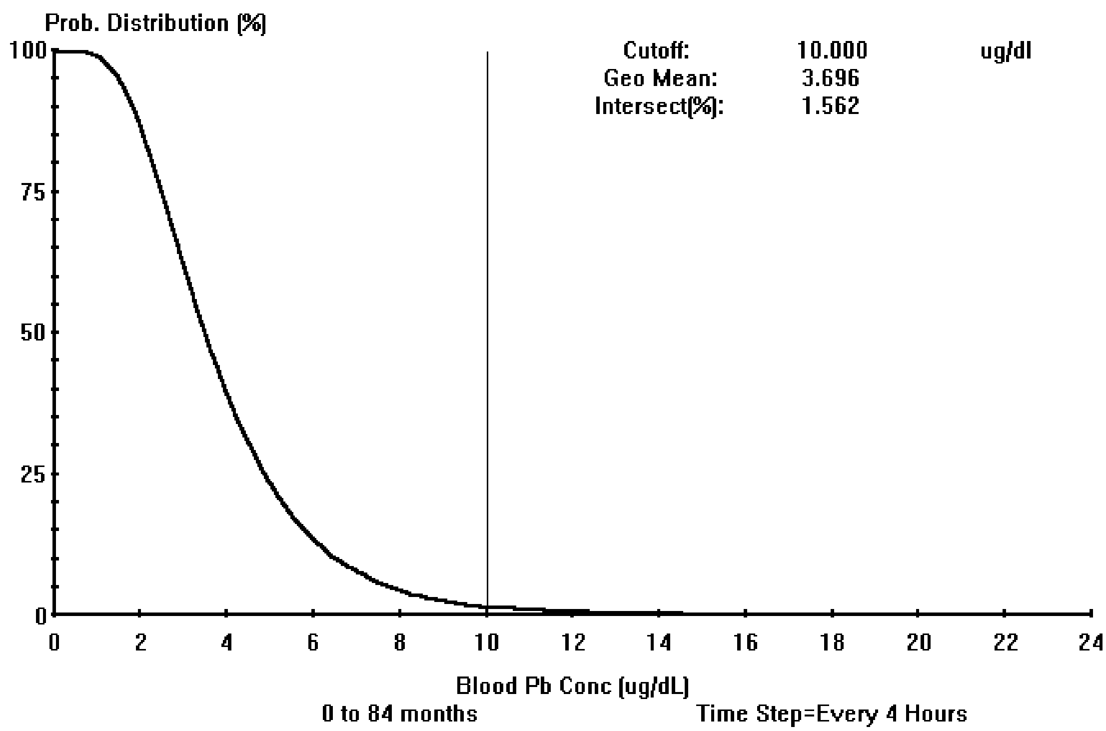

Figure 2. Group 1, with no intervention. Default IEUBK model parameters were used. The geometric mean (in this case 3.696) is reported because the usual distribution of blood lead concentrations in children is distributed lognormally, and requires transformation to the geometric mean. The Intersect (1.562 %) is the percent of children above the cutoff, which in this case is 10 Fg/dL.

Table 4. Soil and dust exposure parameters for Scenarios 1-6.

SOIL AND DUST INGESTION AND CONCENTRATION					
AGE	**SOIL/DUST INTAKE[6] (mg/day)**	**SOIL/DUST INTAKE[7] (mg/day)**	SOIL Pb CONC[4] (Fg/g)	**DUST Pb CONC[8] (Fg/g)**	**DUST Pb CONC[9] (Fg/g)**
0.5-1	**85**	**43**	200	**200**	**1200**
1-2	**135**	**68**	200	**200**	**1200**
2-3	**135**	**68**	200	**200**	**1200**
3-4	**135**	**68**	200	**200**	**1200**
4-5	**100**	**50**	200	**200**	**1200**
5-6	**90**	**45**	200	**200**	**1200**
6-7	**85**	**43**	200	**200**	**1200**

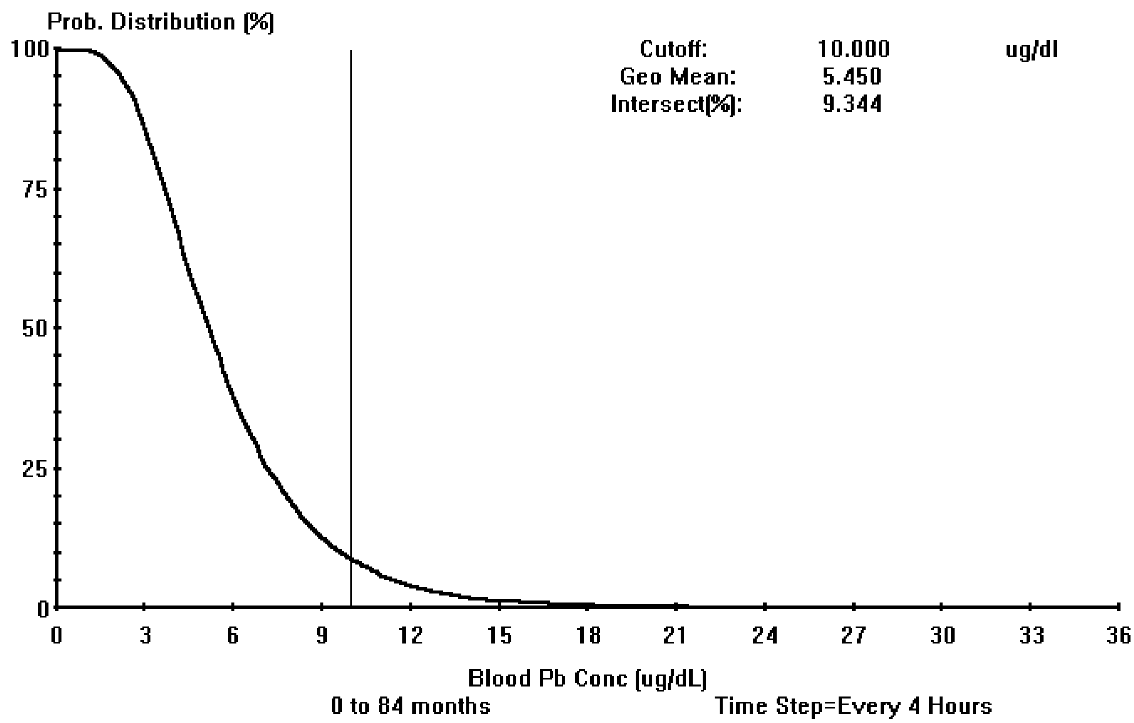

Figure 3. Post-intervention distribution for Group 3 with dust ingestion reduced by 50% but dust concentration remaining at 1200 Fg/g.

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[6]Values indicate typical dust ingestion and apply to scenarios 1and 2.

[7]Values indicate reduced dust ingestion and apply to scenario 3.4,5 and 6.

[8]Values indicate typical dust Pb concentration and apply to scenarios 1 and 2.

[9]Values indicate Pb-based paint impacted house dust and apply to scenarios 3,4,5 and 6.

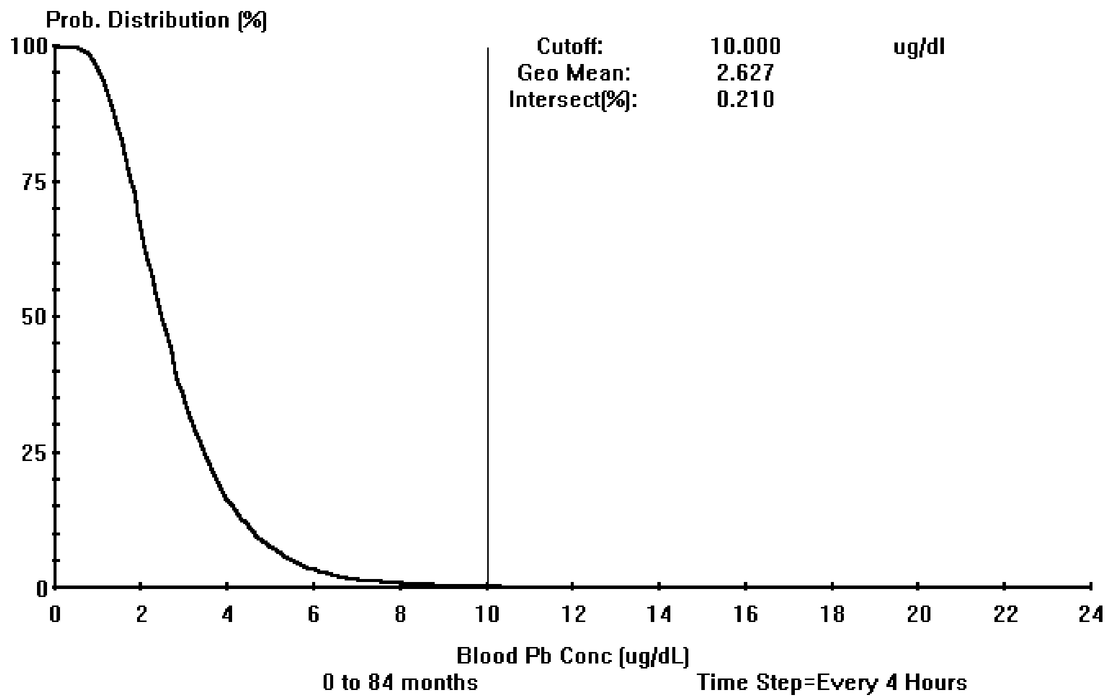

Figure 4. Post-intervention distribution for Group 4 with dust ingestion reduced by 50% and dust concentration reduced to 200 Fg/g. The post-intervention curve for Group 6 is similar, but slightly higher, due to potential exposure to lead from service lines.

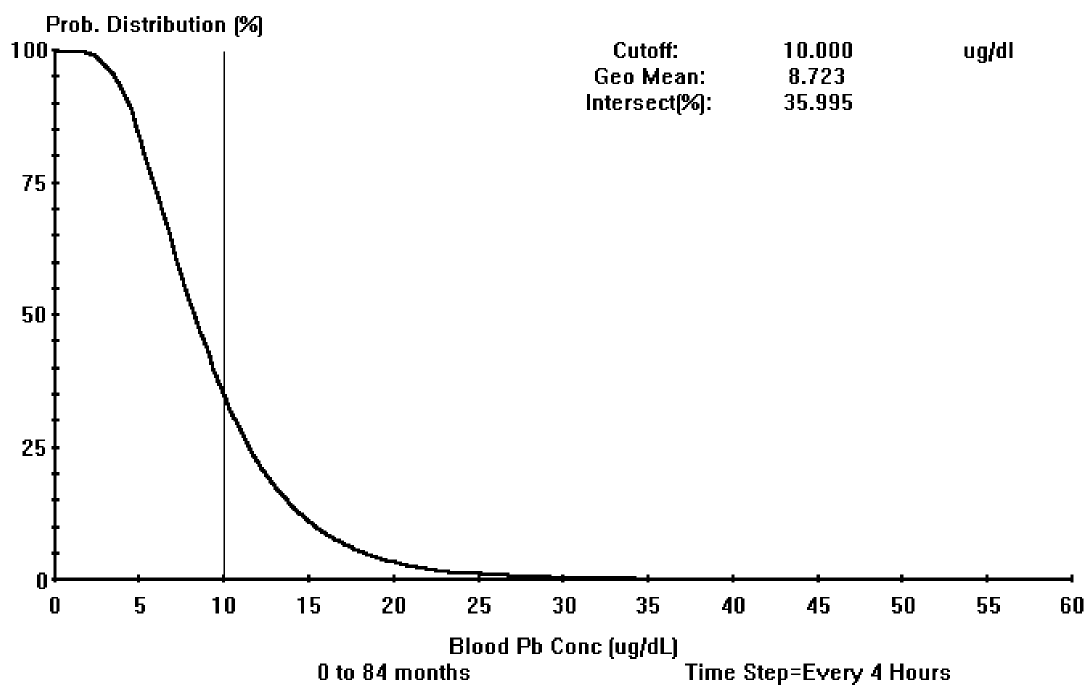

Figure 5. Pre-intervention distribution for Group 3 and Group 4 with normal dust ingestion and dust concentration 1200 Fg/g. Groups 5 and 6 are similar, with a small increase due to Pb in service lines (see Table 5).

Table 5. Expected changes in blood lead concentration without Project XLC. Intervention in this case would be replacement of the Pb service line.

SUMMARY OF MODEL OUTPUTS BY SCENARIO GROUP				
	Before Intervention		After Intervention	
	Geometric Mean Blood Lead (Fg/dL)	Percent of Population above 10 Fg/dL	Geometric Mean Blood Lead (Fg/dL)	Percent of Population above 10 Fg/dL
Scenario Group 1	3.7	1.6	3.7	1.6
Scenario Group 2	4.1	2.7	3.7	1.6
Scenario Group 3	8.7	36.0	5.5	9.3
Scenario Group 4	8.7	36.0	2.6	0.2
Scenario Group 5	9.0	38.1	5.8	12.0
Scenario Group 6	9.0	38.1	3.0	0.5

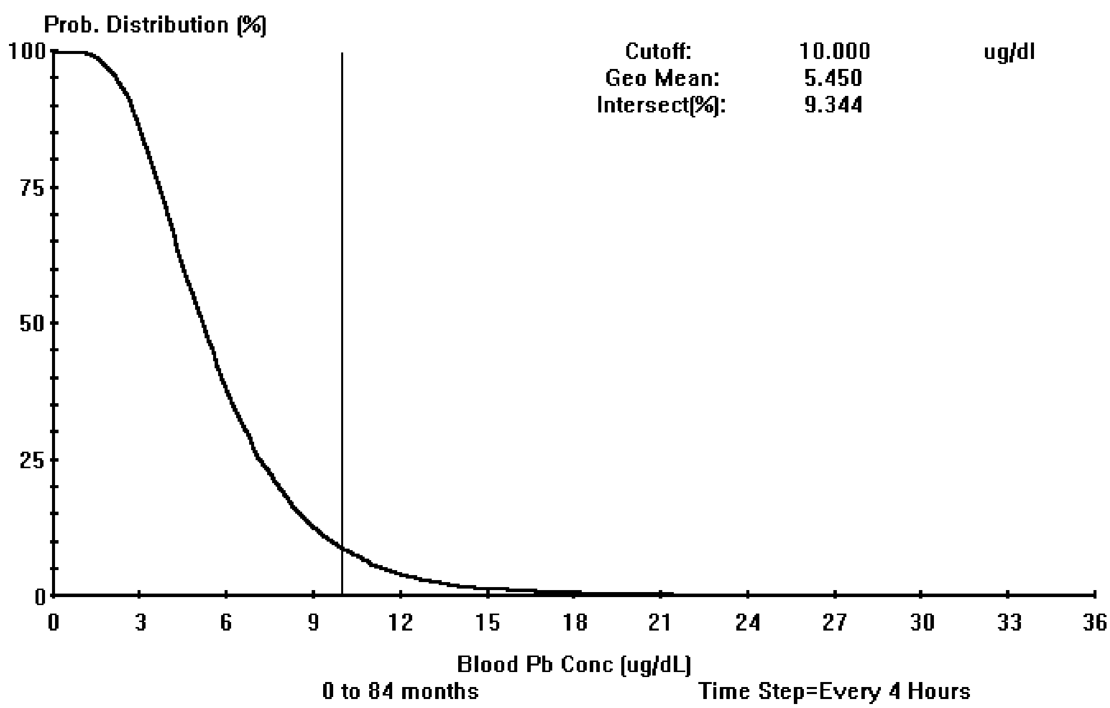

Figure 6. Post-intervention for Group 5 with 15 Fg/L in first draw drinking water, dust ingestion rate reduced 50%, and dust concentration remaining at the pre-intervention value of 1200 Fg/g.

Table 6. Estimate of benefits for each scenario group, based on the predicted reduction in the percentage of the population that would exceed the 10 Fg/dL level of concern.

ESTIMATES OF BENEFITS BY SCENARIO GROUP				
	Estimated Population Size[10]	Estimated change in blood Pb (Fg/dL)	Estimated change in % of population at risk	Estimated reduction in number of children at risk
Scenario Group 1	10500	0.0	0	0
Scenario Group 2	2500	0.4	1.1	28
Scenario Group 3	21000	3.2	26.7	5607
Scenario Group 4	500	4.1	35.8	179
Scenario Group 5	5400	3.2	26.1	1409
Scenario Group 6	100	6.0	37.6	38
Total in all Scenario Groups	40000			N/A
Total in Scenario Groups 3-6	27000			7233

This benefits analysis shows that a decrease of dust lead from lead-based paint is the most important component of the risk assessment, and that reductions in lead in water has comparatively modest incremental benefits in the Columbus situation. The exposure calculations are based on the assumption that dust is the route of exposure, and that the child ingests normal amounts of dust. A child who has pica for soil or paint chips would not be covered by this analysis, but in either case, the expected blood lead concentration would be significantly higher than that calculated here for dust ingestion. It is likely that the parental education program, which instructs parents to teach their children not to eat soil or paint, would mitigate the pica situation, an additional benefit not included in the above calculation of benefits.

The dust lead concentration, 1200 Fg/g, is lower than that typically found in homes with a substantial amount of chipping and peeling lead-based paint. The concentration of lead in the chips alone might be as high as 350,000 Fg/g, so that only a few chips could have a substantial impact on the house dust lead concentration.

[10] The estimated population size (numbers of children in each scenario group) is based on data collected during the Pb study in Columbus during 1995-97, and several assumptions about these data. These assumptions are discussed in the text.

Summary of comparative benefits.

Like most metropolitan areas in the United States, some children in Metropolitan Columbus are exposed to lead from lead service lines connecting the drinking water distribution system to the individual home, and some children are exposed to lead-based paint in their homes. Moreover, some children may be exposed to lead from both sources. By today's standards, children are considered to be at risk if their blood lead concentration exceeds 10 Fg/dL.

This comparative benefits analysis identifies the groups of children at risk, the types of treatment they are likely to receive with either the Pb-service line replacement program or the Pb-based paint intervention program (LSCP). With neither a lead service line replacement or a lead paint intervention program in place, children in Columbus would probably fall into exposure scenario 1 (no Pb service line or Pb-based paint), 2 (Pb-based paint) , 3 (Pb service line) or 6 (both Pb service line and Pb-based paint). Replacing service lines would make children in scenario 3 comparable to scenario 1, and children in scenario 6 comparable to scenario 2. This effect is small (a decrease of 1-2% in the number of children at risk i.e. blood lead over 10 Fg/dL) compared to the impact of the Pb-paint intervention program. Children in exposure scenario 6 would become comparable to exposure scenario 3, and those in scenario 2 would become comparable to scenario 1, for a decrease of about 34-36% in each case.

Estimates of the population size are based on the assumption that the total childhood (age 0-6) population for the city of Columbus is approximately 40,000, a number derived from information from the 1995-97 study that should 31,000 children were screened during this period. Allowing that some children might not have been screened and that the population might have increased since this period, the number 40,000 seems reasonable.

This population of 40,000 children is distributed between two groups: those in Scenario Groups 1 and 2 who will not be in the LSCP because they live outside the central area with a high incidence of lead-based paint. On third, or about 13,000 children are assigned to this group, 10,500 in Scenario Group 1, and 2500 in Scenario Group 2. Of the remaining 27,000 children (Scenario Groups 3-6), all will receive benefits for parental education and about 600 (500 in Scenario 4 and 100 in Scenario 6) will receive benefits from Pb-based paint hazard abatement.

The comparative benefits analysis for Metropolitan Columbus, Ohio suggests that replacing the Pb service lines, in the absence of Pb-based paint in the child's environment, would reduce the percentage of children in this subpopulation who are above 10 Fg/dL by about 1%. A conservative estimate is that about 28 children (scenario group 2 on Table 6) would be shifted to the lower group. This analysis assumes that lead is actually leached from the service lines; actual experience in the City of Columbus is that with the current chemical treatment, the leaching of lead from Pb-service lines has been reduced to negligible amounts compared to lead released from other sources, such as brass fittings or Pb-soldered copper pipes. Therefore, it is a reasonable upper bound estimate of the number of children who would drop below 10 Fg/dL without the provisions of Project XLC, i.e. the LSCP.

On the other hand, an aggressive program of Pb-based paint intervention, which would include parental education targeted to the neighborhoods with a high incidence of Pb-based paint, as well as a screening program that identifies problem homes that require paint removal or stabilization, would reduce the percent of children above 10 Fg/dL by about 27%. This means that the number of children currently at risk would be reduced by about 7300 (scenario groups 3-6 on Table 6). For some of these children, the risk may have been high enough to require individual case management and possibly medical treatment. Furthermore, additional children moving into or born into the community over time would benefit from reduced risk as the stock of housing with Pb-based paint is either renovated or removed by attrition.

One aspect of this analysis that is not evaluated is that families move between neighborhoods and into/out of the community, and children are born into families. This means that over the course of this program, expected to continue for fifteen years, the potential number of children who would benefit from the intervention would be far greater than the estimates on Table 6, which are based on a snapshot of the current population.

Finally, it would be helpful to consider extreme cases that might be overlooked by focusing on benefits to the mean or 50th percentile of the population's exposure. Specifically, the potential for exposure to drinking water concentrations higher than 15 Fg/L. Table 7 shows the expected blood Pb concentrations at several first draw drinking water concentrations under other exposure conditions the same as Tables 3 and 4 that were used for Scenario Group 2. No population estimates are made because no information is available on the numbers of children who might be affected by these drinking water concentrations. One interesting point is that at 150 Fg/L, the drinking water exposure produces a mean blood lead concentration comparable to dust at 1200 Fg/g, as seen for Scenario Group 3 on Table 5.

Table 7. Expected blood lead concentrations at selected first draw drinking water concentrations in excess of those expected in the Columbus Project XLC. Other exposure parameters are default IEUBK model values.

First Draw Drinking Water Concentration Model Input (Fg/L)	Predicted Blood Pb Concentration (Fg/dL)	Predicted % Above 10 Fg/dL
15[11]	4.1	2.7
30	4.6	4.7
50	5.3	8.2
100	6.9	21.0
150	8.4	34.0
175	9.1	40.3
200	9.9	47.5

[11] From Table 5, Scenario Group 2.

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U.S. Environmental Protection Agency. 1994. Guidance Manual for the Integrated Exposure Uptake Biokinetic Model for Lead in Children. EPA/540/R-93/081, February 1994.

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