Report to the Governor's Tar Creek Task Force

Health Effects Subcommittee

March 30, 2000

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LEAD HEALTH EFFECTS AND EXPOSURES IN OTTAWA COUNTY

SUMMARY

Mining wastes in Ottawa County contain significant amounts of lead, cadmium, and arsenic, all of which are known to produce negative health effects. Since these elements are toxic and have no beneficial physiological properties, exposures should be reduced to the lowest level possible. The toxic effects of lead are most pronounced in children under seven years of age and the damages caused by childhood lead exposure are irreversible. The effects of long-term, low-level exposure to cadmium and arsenic, are less well known; however, there is considerable evidence to suggest that such exposures have a negative impact on health.

The use of mining waste in construction, road building, and other activities during the past century has resulted in widespread contamination of soils at the Superfund site. Testing has also shown that environmental exposures are not restricted to the boundaries of the Superfund site as blood lead levels are elevated above State and National averages in surrounding communities, such as Miami. The true extent of soil contamination from mining waste use in northeastern Oklahoma has yet to be determined.

Blood lead testing during the 1990s confirmed that elevated blood lead levels were a serious public health problem in Ottawa County with over 40% of children affected in some communities. Studies of the prevalence of elevated blood and environmental exposures have demonstrated that residential soil, dust, and paint are all significant sources of lead exposure in Ottawa County. Many behavioral factors that are significantly associated with lead exposure or which may exacerbate exposures to physical sources have also been identified. Similar blood lead and environmental exposure assessments were conducted during 1996 and 1997. The prevalence of elevated blood lead levels was found to have decreased significantly (over 40%) during this period in some communities while some environmental exposures were also reduced. A broad range of physical remediation strategies and educational efforts have been effective in reducing the prevalence of elevated blood lead levels; however, all of these efforts will need to be continued in order to adequately address lead-related health issues in Ottawa County

HEALTH HAZARDS OF MINING WASTE

Neither lead, cadmium, nor arsenic are required elements for human nutrition; therefore, they have no positive benefit for human health. Given that these elements are also toxic, exposures should be kept at the lowest level that is practically achievable. Most of this report will focus on lead since this appears to be those most important exposure in Ottawa County, based on our current knowledge, and since more is known about the effects of chronic lead exposure on human health than for the other two elements.

There has been considerable research to determine the level of lead that is toxic to humans and this debate continues. One reason for this controversy is that the physiological effects of lead at low doses are subtle and difficult to quantify. Despite some uncertainty, the U.S. Centers for Disease Control and Prevention (CDC) has steadily reduced what it considers to be an acceptable level of lead in blood for children less than 7 years of age and the standard is now set at 10 micrograms per deciliter (μg/dL). It should be noted that some consideration has been given to lowering this value even further. Since this value is so low, daily exposures must be kept in the microgram range. For example, the U.S. Food and Drug Administration recommends a maximum daily food dose of 6 micrograms (6 millionths of a gram).

Acute toxic effects of lead include: nausea, colic, anemia, severe brain and kidney damage, miscarriage, and damage to the male reproductive system (for a more thorough discussion of lead toxicity, see Appendix A). Acute and chronic exposures to lead are particularly harmful to the developing fetus and children during the first 72 months of life. Exposure to lead during these periods may cause brain damage, loss of visual or auditory response, behavior problems, hyper-activity and deficits in: potential Intelligence Quotients (IQ), attention, and learning. Lead has also been implicated in decreased stature of children. Neurotoxic pediatric effects have also been observed, with interference in neural tube formation and auditory deficits being the most frequently found outcomes.

Lead is one of the few environmental contaminants with a reliable marker for recently absorbed dose. Blood lead levels increase incrementally with exposure to lead in a form which the body can absorb. In adults, 90% of the lead ingested or inhaled is eliminated through the digestive process. In children, only 30-40 % of the lead in the gut is excreted. Mechanisms of action for lead toxicity include inhalation and subsequent absorption in the lung, which can result in an increase in lead in the blood stream. Lead can also be ingested with contaminated soil or house dust. In small children who have frequent contact with floors, windowsills and possibly chipping paint; ingestion is the primary route of exposure.

In 1988, lead was reduced to an allowable limit of 0.1 g/gallon of gasoline. This reduction has been a major factor in recent childhood and adult blood lead reductions. Abatement of residential soil has been shown to produce a persistent reduction in blood lead levels. A study in Boston where soil levels in yards averaged 1500 parts per million (mg/Kg) lead showed a decrease of 2.44 μg/dL 10 months after removal of contaminated soil from yards. This was a much greater decrease than blood lead levels from a control group without contaminated yards. However, for those children with high interior dust levels of lead, abating the soil in the yard alone did not provide prolonged declines in blood lead levels.

Mining wastes in Ottawa County also contain significant concentrations of cadmium and arsenic. During the past few years, Ottawa County residents have expressed concern over the possible health effects of cadmium. Chronic low-level exposure to cadmium has been found to be associated with kidney damage, lung damage, lung cancer, and high blood pressure. Chronic low-level exposure to arsenic has been associated with decreased production of red and white blood cells, abnormal heart rhythm, blood vessel damage, and nerve damage. The health effects of cadmium and arsenic in Ottawa County are currently unknown; however, the prevalence of this metal in soils and mining waste, create the potential for significant effects on the public health.

LEAD STANDARDS

Lead standards vary by medium and are generated by CDC, EPA, and the U.S. Department of Housing and Urban Development (HUD) (Table 1).

Table 1. Lead Standards by Medium

Medium	Standard	Agency
Children's Blood	10 μg/dL	CDC
Soil	500 mg/Kg	EPA
Floor Dust	100 μg/ft^2	HUD
Window Sill Dust	500 μg/ft^2	HUD
Paint	1.0 mg/cm^2	HUD

HISTORY OF BLOOD LEAD SAMPLING

Routine blood lead screening at the Ottawa County Health Department and the Indian Health Service in the early mid-1990s revealed a very high prevalence of children with elevated blood lead levels. These efforts suggested that as many as 40% of children in some areas had elevated blood lead levels, although no population-based estimates were available. When compared to the nation-wide prevalence of 4.4% and an Oklahoma prevalence of 3.2%, the potential magnitude of the problem in Ottawa County became even more alarming. Between 1994 and 1998, over 1,000 children were tested for elevated blood lead levels in Ottawa County. The overall rate of elevated blood lead levels was approximately 11% and was as high as 33% in Picher.

CHAMP Project

A consortium of mining companies approached the Ottawa County Health Department and the Oklahoma State Health Department about conducting a more systematic blood lead screening combined with a community education effort. Eventually, the county, state, and mining companies contracted with the University of Oklahoma Health Sciences Center, College of Public Health to conduct the blood lead study and educational program which came to be known as the Community Health Action and Monitoring Program (CHAMP).

The CHAMP study consisted of the following components:

- a comprehensive blood lead study, including a thorough nutritional assessment, of children age 6 months through 6 years (164 children tested) and pregnant women (12 pregnant women tested);
- quarterly follow-up blood lead screening of children with elevated blood lead levels;
- environmental assessment of 111 homes;
- coordination of professional cleaning of homes to remove dust lead sources for children with elevated blood lead levels;
- quarterly one-on-one lead prevention education for families of children with elevated blood lead levels; and
- community-wide lead prevention education activities.

CHAMP Results:

- ***31.1%*** of all children tested had elevated blood lead levels
  - percent of children with elevated blood lead levels by community
    - **Picher/Cardin = *43%***
    - **Quapaw = *13%***

A number of lead exposure sources were found in each of the towns tested (Table 1). Almost every (97%) home in Picher/Cardin had at least one source of lead exposure (greater than referenced standards) as compared to 77% in Quapaw. The prevalence of dust and paint exposures sources were similar for the two towns with the major difference being the very high number (96%) of homes with an elevated soil lead value. Soil, dust, and paint were all found to be significantly associated with elevated blood lead levels.

Table 2. Number of Homes with Lead Sources (CHAMP)		
Lead Source	**Picher/Cardin (% homes)**	**Quapaw (% homes)**
Soil	96	59
Dust	30	20
Paint	56	43
Any Source	**97**	**77**

<u>TEAL Project</u>

Based upon the preliminary findings from CHAMP, the College of Public Health received funding from the National Institute of Environmental Health Sciences (NIEHS) to study the problem in greater depth, over a wider geographical area, and to implement a community-based intervention effort to address lead issues. This became known as the Tribal Efforts Against Lead (TEAL) project. The TEAL project was designed to extend the assessment efforts to surrounding communities outside of the Superfund site (including Miami) and to work with the community to develop lead prevention efforts at the local level, primarily working with tribal members and local health agencies.

A population-based representative sample of homes was conducted in Miami, Wyandotte, N. Miami, Commerce, Quapaw, Peoria, Picher, Cardin, and Hockerville. Staff visited 5,572 residences and collected blood from 331 children ages 6 to 84 months. Environmental samples were collected from all homes where a child with an elevated blood lead level was identified and on a random sample of other homes, for a total of 245 environmental assessments. An additional blood lead screening will be conducted in Summer 2000.

TEAL Results:

- ***11%*** of children tested had elevated blood lead levels
  - percent of children with elevated blood lead levels by community:
    - **Picher/Cardin/Hockerville = *23%***
    - **Quapaw/Commerce = *12 %***
    - **Miami = *8 %***

A number of lead exposure sources were found in each of the towns tested (Table 3). North Miami and Commerce had the greatest number of homes with at least one source of lead. Soil lead data were significantly lower in Picher/Cardin, and Quapaw than during the CHAMP study. Contaminated paint was found to be the most prevalent source of lead in all communities.

Table 3. Number of Homes with Lead Sources (TEAL)					
Lead Source	**Picher/Cardin/ Hockerville (% homes)**	**Commerce/ N. Miami (% homes)**	**Miami (% homes)**	**Quapaw (% homes)**	**Wyandotte (% homes)**
Soil	15	35	23	13	0
Dust	7	38	25	18	10
Paint	43	78	64	44	30
Any Source	**51**	**84**	**74**	**51**	**30**

STATISTICAL RELATIONSHIP BETWEEN ELEVATED BLOOD LEAD, ENVIRONMENTAL EXPOSURES, AND BEHAVIORAL FACTORS

An extensive effort was directed towards determining the relative influence of the factors that could have influenced elevated blood lead levels. For a more detailed discussion of the statistical significance of various risk factors, see Appendix B. These factors were examined in several different ways. In the first, environmental and behavioral factors were examined separately as part of a bivariate analysis, that is, each factor was examined without considering the influence of other factors. This allowed a better overall assessment of the data as the importance of each risk factor was considered individually. As seen in Table 4, a number of environmental and behavioral factors were found to be significantly associated with elevated blood lead levels.

Table 4. Statistically Significant Environmental and Behavioral Risk Factors Associated with Elevated Blood Lead Levels (Bivariate Analysis)

RISK FACTOR
floor dust
yard soil
chat driveway
interior paint
recent home renovation
parent's education (high school or less)
"hand to mouth" behaviors
child cleanliness
home cleanliness
parental occupational exposure
poverty
high risk hobbies

The second method of analysis employed was Logistic Regression Analysis. This is a type of multi-variate analysis which allows the effects of several factors to be examined simultaneously. It allows a determination of the influence of various risk factors independent of others; therefore, if a risk factor stays in the final model outcome, one can evaluate its relative influence, *independent* of other factors. If factors fall out of the model, this does not mean that they are un-important, merely that the model is unable to discriminate their influence from others. Those factors which were found to be important in the bivariate analysis were entered into the logistic regression analysis. The environmental and behavioral data were each modeled separately and finally all factors were modeled together (Table 5).

All three models show that several environmental and behavioral factors are each independently significant risk factors for elevated blood lead levels. The combined environmental/behavioral model also shows that behavior factors (hand-to-mouth behavior) are just as important as physical exposures to environmental media.

From these data, we cannot conclude which are the most important risk factors; however, a complex statistical analysis is not necessary to determine that the widespread presence of contaminated soil and the remaining mining waste remains the most significant problem. In some homes, paint is clearly the most important problem and the health of the children may not significantly improve until this source of exposure is removed. In many homes, dust is the major source of exposure. Contaminated dust in a home may come from either soil or deteriorating paint, or both. It is unclear (statistically) whether paint or soil is the primary source of contaminated dust overall, but one only has to look at the situation on the ground to see that the mining waste piles and contaminated soil are clearly the major source of concern, although the importance of paint cannot be discounted.

Table 5. Statistically Significant Environmental and Behavioral Risk Factors Associated with Elevated Blood Lead Levels (Logistic Regression Modeling)

Environmental Model	**Risk Factor**
	soil
	chat driveway
	bedroom paint
	floor dust
	mining versus non-mining area
Behavioral Model	
	hand-to-mouth behavior
	child cleanliness
	parents' education
	renovated home
	mining versus non-mining area
Environmental / Behavioral Model	
	hand-to-mouth behavior
	mining versus non-mining area
	floor dust
	bedroom paint
	soil
	chat driveway

CHANGES IN EXPOSURES AND BLOOD LEAD LEVELS

Although the CHAMP and TEAL projects were different in scope and design, the data from the two projects can be compared as a whole in some respect to evaluate change. The most striking difference is the prevalence of elevated blood lead levels between the two studies at the core of the mining area (Table 6). During the CHAMP study, this value was 43% as compared to 23% during the TEAL study. It should be noted that all eligible children in a home were sampled during CHAMP and that only one child per home was tested during TEAL. This could have resulted in an over-estimation of community blood lead levels during CHAMP; however, it is very doubtful that this could explain all of the difference. It seems very likely, therefore, that there was a very significant reduction in the prevalence of elevated blood lead levels.

The reason behind the change in the prevalence of elevated blood lead levels is a subject of considerable interest. The data clearly show that the number of homes with contaminated soil had been sharply reduced by EPA yard removals, with a concurrent reduction in the number of homes with contaminated dust; however, one-on-one educational efforts, community education efforts, and home dust cleanups were also occurring during this period. It is our opinion that all of these efforts contributed to the decrease in the prevalence of elevated blood lead levels and that it is not possible to rank their relative effectiveness. Clearly, the yard removal process has been instrumental in removing one of the major sources of exposure, but as demonstrated by the data, dust and paint remain significant risk factors, or perhaps have become more important. The data also indicate that educational efforts are needed to address behavioral issues. It is difficult to imagine that all contaminated soils can be removed; therefore, education will continue to be important for the forseeable future.

Table 6. Changes Observed Between 1996 – 1997 in Picher/Cardin/Hockerville (PCH) and Quapaw

Factor	PCH 1996 % elevated	PCH 1997 % elevated	Quapaw 1996 % elevated	Quapaw 1997 % elevated
Elevated Blood Lead Levels	43	23	13	5
Soil	96	15	59	13
Dust	30	7	20	18
Paint	56	43	43	44
Any Lead Source	97	51	77	51

CONCLUSIONS:

There are a number of physical and behavioral issues that need to be addressed to reduce the prevalence of elevated blood lead levels in Ottawa County. Lead contamination is not limited to the Superfund site as both lead exposure sources and the prevalence of elevated blood lead levels have been found in towns such as Miami. Current efforts of soil remediation, blood lead sampling, home cleaning, paint removal, and education have had a demonstrable effect on reducing blood lead levels and all should continue.

It is not possible to rank the relative effect of different remediation strategies from the standpoint of reducing blood lead levels, and any meaningful ranking would also include a cost-benefit analysis. For example, educational efforts are very cost-effective as compared to physical remediation. From a regional perspective, the removal of soil and ultimately the remaining mining wastes remains the most important activity for reducing lead exposure; however, since it is difficult to foresee a time when all of the material will be removed, a continued emphasis on blood lead screening and community education is essential. Most of the behavioral risk factors associated with elevated blood lead levels can be reduced through education as can some environmental exposures, especially paint and indoor dust. The prevalence of homes with elevated paint levels, and the high percentage of these homes with deteriorating paint, suggests that this problem is very significant in many individual cases and on larger scale in specific communities. Removing only the soil lead source from a home with a severe paint problem is helpful but may not address the primary source of exposure. From a community standpoint, it may be difficult to reduce blood lead levels to acceptable levels without addressing all sources of exposure.

Finally, the continued use of mining waste in un-controlled construction activities represents a continued and unnecessary source of exposure. Laboratory analysis has shown the majority of lead, cadmium, and arsenic are contained in the finer elements of the mining waste (the sizes most likely to suspended by the wind); therefore, specific emphasis should be placed on controlling dusts and the use of fine materials from the mining waste piles. A larger-scale study of historical mining waste use and the identification of possible contaminated sites should also be conducted to identify additional problem areas which very likely remain undiscovered.

Appendix A

Lead is a naturally occurring element in the earth's crust, with background concentrations in the range of 20 mg/kg of soil. Natural weathering of the earth's crust releases about 19,000 tons per year. Anthropogenic sources yield about 126,000 tons per year, and approximately 3 million tons per year of lead are consumed. Lead is produced by roasting and reducing ore that has been previously milled as lead sulfide (PbS, galena), lead sulfate (PbSO4, anglesite) and lead carbonate (PbCO3, cerusite). Lead is mined from surface or shaft mining mainly as galena, but the ore usually contains other minerals such as copper, zinc, cadmium, silver, lead, gold, bismuth, antimony, arsenic, gallium, thallium, indium, germanium and tellurium.

Acute toxic effects of lead include: nausea, colic, anemia, severe brain and kidney damage, abortion and damage to the male reproductive system. Lead is particularly harmful to the developing fetus and children during the first 72 months of life. Exposure to lead during these periods may cause brain damage, loss of visual or auditory response, and deficits in potential Intelligence Quotients (IQ). Lead has also been implicated in decreased stature of children. Lead is one of the few environmental contaminants with a reliable marker for recently absorbed dose. Blood lead levels increase incrementally with exposure to lead in a form which the body can absorb. In adults, 90% of the lead ingested or inhaled is eliminated through the digestive process. In children, only 30-40 % of the lead in the gut is excreted. Mechanisms of action for lead toxicity include inhalation and subsequent absorption in the lung, which can result in an increase in lead in the blood stream. Anemia is a clinical sign of acute lead poisoning. Lead can also be ingested with contaminated soil, dust or house dust. In small children who have frequent contact with floors, windowsills and possibly chipping paint; ingestion is the primary route of exposure.

Iron status is also an important measurement when determining the relative toxicity of lead. Dietary insufficiencies of iron, calcium or zinc may increase the risk from ingested lead. Decreased hematocrit levels (<35%) have been observed in several studies of lead exposed children. Generally, the effect was only observed at blood lead levels of less that 20 μg/dl. However, the effect was greatest in the youngest children. In a meta-analysis of many studies done on children living near smelters a strong non-linear negative dose-response relationship was demonstrated between children living near a primary lead smelter. The study looked at the correlation coefficients of lead and IQ. The study seemed to indicate a possibility that the effect of lead on IQ did not have a threshold above 10 μg/dL and in fact may have impacts at much lower levels.

Other observed pediatric toxic effects of lead include: neurotoxic effects in children, with interference in neural tube formation and auditory deficits being the most frequently found effects. Behavioral and learning deficits have been shown in several prospective studies of children. Both the Cincinnati and Boston children's studies have observed the effects of prenatal and infant blood leads on subsequent performance in schools. Assessments for social class were performed on a yearly basis using the Home Observation for Measurement of the Environment (H.O.M.E.) survey. After adjustment for co-variates, the observed relationship between blood leads and outcome measures on both the 4 and 5 year old tests were determined to be non-significant. It should be noted that during this time period, blood lead levels were dropping significantly in areas where leaded gasoline had previously been a major source of exposure. It is not clear that either of these cohort studies measured lead levels in the soil in the children's environment.

A recent follow-up study of 281 young adults, exposed as children in the Boston area and a similar unexposed referent group showed significant neurobehavioral deficits in the formerly exposed group. Testing of tibial lead with K x-ray fluorescence was not significant. The authors theorize that stored lead level measurements with the non-invasive procedure may not have been sensitive enough for measurements to be significantly associated with the neurobehavioral test results.

Lead interferes with several of the heme synthesis processes. Lead inhibits 5-aminolevulinate dehydratase (ALA-D) coproporphyrinogen oxidase (COPRO-O) and ferro-chelatase (FERRO-C). Lack of these enzymes depletes heme synthesis and the synthesis of the initial and rate-limiting enzyme 5-aminolevulinate syntheses (ALA). The system compensates with increased production of ALA precursors and coproporphyrin. The circulatory protoporphyrin is bound to zinc. Thus, soils with a combination of lead and zinc may have more or less toxicity than soils with only lead present. This toxic effect of lead has not been linked with any morbidity outcomes in previous studies, but may be related to the hypertension which has been mentioned as an effect of long term lead exposure. In a cross-sectional study in Canada, a correlation between diastolic blood pressure and blood lead (PbB) was statistically significant. The study also included an exposure to cadmium for the same workers, so the data are inconclusive for the lead only exposure, but suggestive for the exposure concurrently to the two heavy metals.

A recent study in British Columbia nested within a larger study of male reproductive health and exposure to lead in a lead-zinc smelter looked at the association between blood lead levels and a particular genotype which is present in approximately 20% of the population that appears to modify the red cell binding of lead and may increase the transport of lead in blood. An alternative to this is that lead bound to blood may retard the deposition of lead in other body compartments. This study looked at differences in zinc protoporphyrin (ZPP) and urinary coproporphyrin (CPU) and ALAD genotypes. The relationship between blood lead and ZPP was confirmed and there appears to be a modification of this relationship by ALAD genotype. The differences were greater at blood lead levels above 40 µg/dL. If ALAD2 makes lead bind tighter to red blood cells and thus is less bioavailable there would be a decrease in the amount of bioavailable lead to inactivate coproporphyrinogen oxidase or to inhibit the insertion of iron into the protoporphyrin IX and lead to lower levels of ZPP and CPU. The Canadian study indicates the opposite effect, with higher ZPP as an indication of inhibition of heme synthesis being more pronounced with the ALAD1 genotype. The authors conclude that further research in the area of genetic susceptibility to the biological consequences of long-term lead exposure is needed to clarify a protective or harmful effect of either genotype.

In adults, chronic exposure to lead has resulted in both peripheral and central nervous system (CNS) effects. In two studies of employees of a firing range and at a battery plant, complaints of CNS disorders were noted. An occupational in 1989 reported increased heart rate and blood pressure in a group of workers removing leaded paint from a metal bridge after as little as four weeks exposure. Blood lead levels ranged from 48 to 120 micrograms per deciliter.

Another larger study failed to find any significant difference in blood pressure in a group of 270 white male battery plant workers and unexposed controls although there were significant differences in blood lead levels. A study of 95 exposed lead smelter workers and matched controls revealed slightly higher levels of ischemic electrocardiographic changes in lead workers than in controls. A slight increase in diastolic blood pressure was also observed in this group. Body burden of lead increases with age, and with duration of exposure. Even after exposure has ceased, and endogenous lead is the source of blood lead, those workers with earlier and longer exposure to lead had higher blood lead levels.

Lead has also been implicated in various forms of nephropathy and hypertension. Cooper conducted several analyses of mortality from workers at lead production facilities. The number of observed deaths overall in the two large cohorts was greater than expected in workers from 1946-1972. The deaths were mainly from malignant neoplasms, chronic renal disease and nephropathy. There was, however, no control for confounding factors such as smoking, ethnicity and diet. Levels of lead in bone, measured by K X-ray fluorescence, were associated with increased odds of developing hypertension in a subset of 590 male subjects in the Normative Aging study. The authors, were unable to adequately determine past dietary or smoking habits or alcohol consumption. Another recent development with data from the Normative Aging Study indicates that a 10 microgram/gram increase in tibia lead measured by x-ray fluorescence was associated with an odds ratio of 2.23 for intraventricular blockage in men less than 65 and an increased odds ratio of 1.22 for AV block in men greater than 65. It has been theorized that cumulative exposure to lead may depress cardiac conduction. In this study, there was no association of results with measured blood lead levels.

In 1988, lead in gasoline was reduced to an allowable limit of 0.1 g/gallon of gasoline. This reduction is a major factor in recent childhood and adult blood lead reductions. Abatement of residential soil has been shown to produce a persistent reduction in blood lead levels. A study in Boston where soil levels in yards averaged 1500 parts per million (mg/kg) lead showed a decrease of 2.44 μg/dl 10 months after removal of contaminated soil from yards. This was a much greater decrease than blood lead levels from a control group without contaminated yards. However, for those children with high interior dust levels of lead, abating the soil in the yard alone did not provide prolonged declines in blood lead.

Appendix B

A number of environmental and behavioral factors were found to be associated with elevated blood lead levels (Table 1). The distribution of each risk factor was compared to the distribution of elevated blood lead levels to calculate an Odds Ratio. An Odds Ratio provides information about the association between the factor and the outcome (elevated blood lead level). The higher the Odds Ratio, the stronger the relationship between the two. A generally accepted standard is that an Odds Ratio over 2.0 is strongly suggestive of a positive relationship between the risk factor and the outcome. Floor dust and soil clearly stand out as having the strongest association; however, other environmental and behavioral factors are also clearly associated with elevated blood lead levels. Odds Ratios are useful for discussion purposes, although some caution should be exercised in ranking these risk factors based on Odds Ratios, since many of the Odds Ratios are similar and most of the confidence intervals overlap. When confidence intervals overlap, the ability to distinguish between the relative importance of risk factors is not supported with a high degree of statistical confidence.

Table 1. Statistically Significant Risk Factors Based on Bivariate Analysis of Factors Associated with Elevated Blood Lead Levels

Risk Factor	Odds Ratio	Confidence Interval
Floor Dust ($\geq$100 ug/ft^2)	9.2	1.2, 105.4
Yard Soil ($\geq$500 mg/Kg)	12.0	1.8, 71.6
Chat driveway	3.3	1.5, 7.3
Interior Paint with lead	3.8	1.7, 8.4
Recent Home Renovation	2.4	1.2, 4.7
Parent's Education (high school or less)	3.5	1.5, 8.0
"Hand to Mouth" Behaviors	6.0	2.9, 12.3
Child Cleanliness	5.8	2.5, 13.7
Home Cleanliness	4.3	2.0, 9.6
Parental Occupational Exposure	2.4	1.0, 5.1
Poverty	2.3	1.4, 5.4
High Risk Hobbies	2.8	1.4, 5.7

The second method of analysis employed was Logistic Regression Analysis. This is a type of multi-variate analysis which allows the effects of several factors to be examined simultaneously. It allows a determination of the influence of various risk factors independent of others; therefore, if a risk factor stays in the final model outcome, one can evaluate its relative influence, *independent* of other factors. If factors fall out of the model, this does not mean that they are un-important, merely that the model is unable to discriminate their influence from others. Those factors which were found to be important (odds ratio $\geq$2.0) were entered into the logistic regression analysis. The environmental and behavioral data were each modeled separately and finally all factors were modeled together (Table 2).

All three models show that several environmental and behavioral factors are each independently important risk factors for elevated blood lead levels. Perhaps the most interesting data is seen for exposure to soil and driveways. In homes with one of these exposures, a child is a slightly higher than two-fold (2.1) risk of having an elevated blood lead level while a child in a home with both contaminated soil and a chat driveway is at more than four (4.3) times greater risk. This is referred to as a dose response effect and is very compelling for implicating soils and chat driveways as a major source of lead exposure. The combined environmental/behavioral model also shows that behavior factors (hand-to-mouth behavior) are just as important as physical exposures to environmental media.

Table 2. Logistic Regression Models of Environmental and Behavioral Factors

Environmental Model	**Risk Factor**	**Odds Ratio**	**Confidence Interval**
	high soil* ***or*** chat driveway	2.1	1.2, 3.7
	high soil* ***and*** chat driveway	4.3	1.4, 13.4
	bedroom paint	3.5	1.3, 9.5
	floor dust	4.7	1.8, 12.0
	mining versus non-mining area	6.1	2.3, 16.5
Behavioral Model			
	hand-to-mouth behavior	8.8	3.6, 21.4
	child cleanliness	4.6	1.8, 12.1
	parents' education	3.5	1.2, 10.2
	renovated home	2.7	1.2, 6.3
	mining versus non-mining area	4.3	1.8, 10.2
Environmental / Behavioral Model			
	hand-to-mouth behavior	5.7	2.1, 15.4
	mining versus non-mining area	6.8	2.3, 20.3
	floor dust	5.5	2.0, 15.3
	bedroom paint	3.4	1.2, 10.1
	high soil* ***or*** chat driveway	2.0	1.1, 3.9
	high soil* ***and*** chat driveway	4.1	1.1, 15.3

* defined as >176 mg/Kg (fourth quartile distribution)

Appendix C

Current and Planned Health Related Actions

Ottawa County Health Department

The Ottawa County Health Department is the primary resource for blood lead testing in Ottawa County. The Ottawa County Health Department has been working under a cooperative agreement with ATSDR for the past year and a half. The overall workplan includes blood lead screening of children 6 months through 6 years of age and pregnant women using the Lead Care portable blood lead testing analyzer. This instrument allows for increased portability and opportunities for lead testing as well as results that can be given to parents within 5 minutes. This timely reporting allows for better one on one education with children and families. The Health Department has done screening throughout the county in Head Start and preschool programs. Plans are underway to provide lead screening along with immunizations for all kindergarten children throughout the county during annual enrollment (the month of April 2000). The Health Department has initiated these screenings in older children in order to coordinate effort with the OU College of Public Health's TEAL Project who plans to do venous blood lead levels in at least 335 children in Ottawa County starting in May/June 2000. Following completion of TEAL's blood lead screening, the health department plans to provide education and screening in all day care centers throughout the county as well as remote sites through the mobile unit provided by Integris Baptist Regional Hospital in Miami. These plans along with coordinated screening with WIC and Immunization services within the health department and efforts through Indian Health Service should make screening readily available for children 6 months through 6 years of age.

Agency for Toxic Substances and Disease Registry (ATSDR)

ATSDR has proposed a study to better characterize the extent of residential dust contamination in areas outside of the Superfund Site. Residential surveys revealed that construction activities in the past have included using chat as backfill in home foundation construction. Due to the chemical nature of chat, severe corrosion of the air handling ductwork eventually occurs potentially leading to the entry of lead-contaminated dust into homes. Residential dust contamination from this process has been measured; however, the geographical extent and health impacts have not been thoroughly assessed.

University Studies

Harvard University has received funding to complete a study of adolescent children and exposure to lead. As part of this study, researchers will measure the amount of lead in bone, using a portable X-ray instrument, which will provide an excellent measure of cumulative exposure over a child's life. These values will be compared to scholastic and behavioral performance to investigate the effects of long-term lead exposure on child development.

As part of the on-going TEAL project, the University of Oklahoma Health Sciences Center will conduct an additional population-based blood lead screening during Summer 2000. The University has also requested additional funding from the National Institute of Environmental Health Sciences to continue its community-based intervention effort and assessment of environmental factors. The continuation of the intervention effort will extend and re-direct the current program towards youth. The environmental component will focus on better understanding characteristics of lead-contaminated dust in homes.