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BLOOD LEAD LEVELS IN GALENA, KANSAS
A HEAVY METAL MINING SUPERFUND SITE

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Submitted by

KANSAS DEPARTMENT OF HEALTH AND EVNIRONMENT

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ABSTRACT

A prevalence study of blood and environmental lead levels was conducted in Galena, Kansas, a heavy metal mining Superfund site. The area was part of an abandoned lead/zinc mining and smelting region oftentimes called the Tri-State Mining District (Kansas, Missouri, and Oklahoma). This follow-up study was done in 2000, and follows an earlier 1991 investigation. The earlier study had found a significant association between environmental lead levels and blood lead levels. In the earlier study blood lead levels in children in the exposed area were elevated above levels in children in a control area. Since then the U.S. Environmental Protection Agency has remediated 697 properties and five day care centers in Galena. It is important to evaluate the effect of this remediation on the blood lead levels in children and lead levels in the environment.

Methods of this study included a venous blood sample collected from children aged 6-72 months, environmental samples in soil, dust, and paint (indoor and outdoor), and an interview questionnaire. The sample included 72 homes (with 100 children) selected after a mailing of a recruitment questionnaire to all homes in Galena. The sample included about one-third of the children residing in the city in the year 2000 U.S. census. Although no control city was utilized for comparison in this latest study, results were compared against changes in U.S. blood lead levels in children and internal comparisons were made between blood lead levels in remediated and non-remediated yards. Results comparing 1991 to 2000 showed that environmental lead levels had declined 9.7% for soil lead and 2.8% for dust lead. Mean blood lead levels had declined by 45.7%, compared to about 32% estimated for the overall U.S. population for the 1991 – 2000 period. The percentage of children exceeding 10ug/dL of blood lead declined from 10.5 to 6.0 % (p=0.36). This compares to about 7.6% estimated for the overall U.S. population for 1998. Comparisons with 1991 data are problematic, however, due to incomplete data from 1991 and somewhat different methodologies between the two surveys.

Using multivariate analysis on data from the year 2000 survey, the major risk factor was mouthing furniture. However, male sex, lack of air conditioning, the log of the maximum lead value in soil, and the swallowing of non-food items were also predictive of elevated blood lead levels. From an outdoor environmental perspective, there still was a statistically significant association between environmental soil lead levels and blood lead levels in children. Despite the extensive amount of education and soil remediation there was not a significant reduction in mean soil or dust lead levels. There was, however, a reduction in blood lead levels in children that possibly could be attributed to either the educational intervention, the environmental intervention, or some combination of both.

INTRODUCTION

From 1876 to the 1960's the Tri-State Mining District of Kansas, Missouri, and Oklahoma produced extensive amounts of lead and zinc. The district includes Cherokee County, Kansas; Jasper County, Missouri; Newton County, Missouri; and Ottawa County, Oklahoma. The area was the world's largest producer of zinc during World War II. Smelters were also located in the area. Although mining started as surface mining in Missouri, the depth of the field gradually deepened to become underground mining as one moved west into Kansas and Oklahoma. Depths eventually reached several hundred feet in the western mines. After the war the area gradually declined in productivity until the last mines was finally closed in 1970. Galena, Kansas was part of the area and had one of the smelters. Figure 1 shows the location of Galena in southeast Kansas (KS).

When mining and smelting operations were discontinued, a considerable amount of mine and smelter wastes remained on the soil surface, with up to 3,800 ppm of lead found by the U.S. Environmental Protection Agency (EPA) in mine wastes and tailings (Agency for Toxic Substances and Disease Registry, 1996). In addition, there are thousands of boreholes left along with other larger openings to the mines. The municipal water supply of Galena was not found to be contaminated with heavy metals, although a number of the private water wells surrounding the town were. Because of heavy contamination of private wells with metals such as lead and cadmium, bottled water was provided to area residents until a rural water district expansion was able to provide a suitable water supply. In 1985, the EPA declared the Cherokee County portion of the district a Superfund site. The water district was new and completed by EPA as a cleanup action (operable unit #1, Galena Operable Water Supply; OU-1) in the Galena subsite of the Cherokee County Superfund site. The three contiguous counties were evaluated separately by their respective states.

Prior to remediation of the Galena subsite by the EPA, known as operable unit #7 (OU-7), Galena Residential Soils, the Agency for Toxic Substances and Disease Registry (ATSDR) contracted with the Kansas Department of Health and Environment (KDHE) to conduct a blood lead study in the area. The study included an evaluation of blood lead levels in children, measurements of environmental lead in soil, dust, drinking water, and paint, and an interview survey of demographic and behavioral characteristics. Relationships between blood lead levels and these other independent variables were evaluated. The study, conducted in 1991 (ATSDR, 1996), indicated that blood lead levels in Galena children were significantly elevated compared to levels in children from a control town. In addition, there was a significant relationship between blood lead levels in children and environmental measurements of lead in the soil. In a subsequent study (ATSDR, 1998), the KDHE indicated a higher prevalence of children with elevated blood lead levels in Cherokee County compared to either the state or national data. In 1995 the EPA initiated abatement activities, known as operable unit #5 (OU-5), Galena Groundwater and Surface Water, including remediation of 900 acres of mining wastes surrounding the community of Galena and filling of shafts and subsidence features at the Galena subsite.

In order to qualify for soil remediation the maximum level of lead in Galena soil had to exceed 800 ppm utilizing discrete sampling per EPA protocol. During the period 1995 – 1998, a total of 697 properties and five day care centers were remediated. Fifteen properties with soil lead levels exceeding 800 ppm continue to be monitored over time and cleaned up. Remediation generally consisted of removing the top 3-4 inches of soil from home (residential) yards, schools, and other areas where young children congregated. Sometimes up to 12 inches of soil were remediated. The soil was replaced with soil from rural areas around Joplin, Missouri that generally contained lead levels of 240 ppm or less. Most of the replacement soil used had 100 ppm or less of lead.

A lead awareness education campaign including seminars and educational/diagnostic information was conducted in the community and among health care providers. This educational campaign was conducted at the same time as the soil remediation. Lead poisoning prevention was incorporated into the local school curriculum and educational materials were provided to parents.

Given that all these remediation activities – including both soil remediation and educational activities - were carried out in Galena, the question arises as to whether the remediation reduced the levels of lead in soil and blood in children. The purpose of this new study, therefore, was to respond to this question. Have blood and environmental lead levels decreased? Is there still an association between environmental lead levels and blood lead levels or is behavior the only predictor of an association?

PURPOSE AND OBJECTIVES

Specific hypotheses to be tested were that: 1) the prevalence of elevated blood lead levels of children living in the Galena subsite lead mining area will be lower than prevalence levels determined during the 1991 exposure study; 2) the mean blood lead levels of children living in the Galena subsite area will be lower than the mean blood lead levels determined during the 1991 study; 3) average environmental lead levels will be lower in 2000 than in 1991; and 4) the relationship between environmental lead levels and blood lead levels will no longer be significant.

Objectives of this study were to determine changes in blood and environmental lead levels and to determine whether or not there still was a relation between environmental and behavioral risk factors and blood lead levels.

METHODS

DATA COLLECTION

KDHE and the Cherokee County Health Department (CCHD) developed a statement of work and opened the field sampling and questionnaire portion of the study for competitive bid. To be eligible for an award, a firm had to be licensed by the state as a lead activity firm and the individual conducting the sampling had to be certified by

KDHE as either a lead inspector or a lead risk assessor. After evaluating the bids received, the bid was awarded to Roger's Consulting Enterprises (RCE) of Columbus, KS.

A community awareness campaign about the study was also conducted. This consisted of TV and radio announcements, newspaper articles, and posters in various public locales. An informational meeting was held by KDHE, CCHD, and RCE at the Galena Community Center in June 2000 to discuss protocols and procedures with Galena residents. The mayor, city council, local media, and the public were invited to attend.

Data were collected for the study during the period July 1 through August 31, 2000. A letter and recruitment form were mailed in May 2000 to all Galena, Kansas addresses listed in the EPA remediation database (Appendix 1). The letter explained the purpose of the study and the qualifications residents must meet in order to participate. The residents were requested to send the enclosed recruitment form back to the Cherokee County Health Department or to call in their response directly to the health department. The material was included in a stamped, self-addressed envelope. In an attempt to reach all potential participants, recruitment forms were made available at WIC clinics in the area. Letters were also sent to registered and licensed day care providers/child care facilities, churches, and home with pre-kindergarten and kindergarten students.

Upon receipt of a response to the recruitment mailing, eligible children and homes were selected based on certain criteria. These criteria were: 1) presence of a child in the home aged 6 to 72 months, 2) residency in Galena City for at least 60 days, and 3) willingness to participate in all phases of the study, including environmental and blood sampling. Instead of returning the survey by mail, some of the families responded in person. If they met all the criteria they were allowed to participate.

Eligible families who met the entrance criteria were contacted by KDHE to provide more information about the study and the opportunity to ask questions. If the family qualified for participation and wished to participate then their phone number was given to the contractor for the questionnaire and field sampling portion of the study. The contractor then contacted the family to set up a time for an interview and environmental lead measurements. The contractor also set up an appointment time to obtain the blood sample. A trained interviewer went to the home and administered a questionnaire to the parents of the child (Appendix 3). In addition, environmental samples were taken of the soil, dust, and paint. Clinics were set up at the Galena Community Building, where nurses took venous blood samples from the child. Samples were transferred to the CCHD. Trained staff were available to retrieve the samples and add the lead care mixing reagent.

Families were reimbursed for their participation in all phases of the study. For each completed interview and blood and environmental lead measurements RCE provided the family with a $50 check.

Because of funding limitations a control town was not included. Instead an internal control was used to compare remediated to non-remediated homes and an external control that used estimates from ATSDR of the change in blood lead levels in children in the U.S. during the 1991 to 2000 period.

Informed consent was obtained for both general participation in the study and before collection of the blood sample (Appendix 2). The Institutional Review Boards of the Kansas Department of Health and Environment and the University of Kansas Medical Center approved this project.

BIOLOGICAL SPECIMEN COLLECTION AND ANALYSIS

Blood collection samples were obtained and then transported to the Cherokee County Health Department (CCHD). The protocol utilized was the same as the CCHD used for all of their blood lead testing (Appendix 4). In accordance with CCHD protocol, elevated levels were not routinely sent to KHEL Laboratories for confirmation. A ten percent sample (n=10) of blood vials were sent to the KDHE laboratories in Topeka, Kansas for comparative analysis for lead. Trained nurses at the health department added a reagent to the blood so that it could be stored and later batch tested. The reagent was added within 24 hours of attainment. The ESA Lead Care instrument uses disposable sensors. Samples were then placed in an ESA Lead Care instrument, an electrochemical method based on anodic stripping voltammetery with a blood lead level range of 1.4 – 65 Fg/dl, where they were immediately read (Lead Care Users Guide). Families and their physicians were directly notified by the local health department of any elevated (> 10 μg/dL) levels found. The instrument was calibrated each day and blood was stored in a refrigerator at the Cherokee County Health Department in Columbus, Kansas. A ten percent sample (n=10) of blood vials were sent to the KDHE laboratories in Topeka, Kansas for comparitive analysis for lead. All residents were notified of their results by mail (Appendix 5). In August 2000, KDHE presented a summary of the number and percent of exceedances to the community.

The 1991 study samples utilized graphite furnace atomic absorption spectroscopy (GFAAS) methodology. The CDC sponsored Clinical Review, "Review of the Performance Characteristics of the Lead Care Blood Lead Testing System", ESA Inc. and And Care, Inc. (Appendix 10) contain data proving that the Lead Care Blood Lead Testing System is an acceptable technical means for screening children with elevated blood lead levels. The Lead Care detection limit was higher than the analytic method used in 1991, but it is not a poorer analytic method (Shannon M and Rifai N, 1997).

ENVIRONMENTAL SAMPLE COLLECTION

Soil collection was conducted at the current home according to an EPA Quality Assurance project plan specifically developed for the 1991 study (1995). Site selection was based on the study protocol (Appendix 8) and included a general yard (non-play) area, a high contact play area, the drip line, the vegetable garden (if any), the unpaved driveway, and other areas (day care facility, or area where the child spends the majority of his/her time). Field blanks were utilized as well for Quality Assurance (QA). Soil remediation data were available for 64 of the 72 homes.

Dust wipe samples were collected from within the current home according to protocol also established by the U.S. Department of Housing and Urban Development (HUD) (1995). Samples were collected from the window sills, floors, and mini-blinds in selected rooms. The rooms selected were the child's bedroom, the main playroom or area, and the kitchen (Appendix). Field blanks were also utilized for QA.

Paint was tested for lead content according to protocol established by HUD (1995). An X-ray fluorescence (XRF) spectrometer was utilized. Indoor paint was evaluated in the child's bedroom, the playroom or area, and the kitchen. Areas checked were the window sills, doors, walls, and ceilings. XRF readings were obtained from the walls, windows, doors, and porches. Physical condition of the paint such as deterioration or presence of paint chips was also noted on each surface tested (intact, fair, or poor according to HUD guidelines). The instrument was calibrated using pre-measured block paint chips every 4 hours.

All residents were notified of their results by mail (See Appendices 6 and 9). The 1991 study determined that there was no lead contamination in the public water supply. Since all homes in Galena are on a public water supply and this supply is continually monitored by KDHE for purposes of meeting the U.S. Public Health Service drinking water standards, there was no need to re-measure the drinking water for lead in the year 2000 study.

DATA ANALYSIS

All blood and environmental laboratory data were entered into an Excel spreadsheet. Questionnaire data were independently entered and verified by an independent review. Laboratory values less than the detectable limits for the instruments (1.4 µg/dL for blood and 50.74 ppm for soil were redefined and entered as one - half the value of the detection limit: i.e., 0.7 and 25.27, respectively). After some preliminary exploratory data analyses, all laboratory measurements were transformed to their natural logarithm in order to approximate a normal distribution for analysis. For environmental values the log of the maximum value was utilized for the independent variable (soil, dust, paint).

Univariate, bivariate, and multivariate analyses were utilized in the analysis. In all cases, a Type I error of 5 percent (alpha < 0.05) and Type II error of 20 percent (beta $<.20$) was utilized in order to determine statistical significance. SAS version 8.0 (SAS Institute, Cary, NC) was utilized.

The univariate analysis included simple frequency distributions of blood lead, environmental lead, and behavioral and demographic variables. The student's t-test was used to compare mean blood lead changes between remediated and non-remediated yards in 2000. The chi-square test was used to compare exceedances in blood lead values for children between 1991 and 2000.

Bivariate analysis consisted of a correlation analysis between environmental and behavioral exposures and blood lead levels as well as analysis of variance models with blood lead level as the dependent variable and each individual exposure variable as an independent variable. For variables measured at the household level (such as household income) the analyses were weighted to account for the correlation between multiple children in the same household. This was done using two-way mixed effects models with each independent variable entered as a fixed effect and house ID entered as a random effect. For correlation analysis the Pearson Product Moment correlation was utilized on the log transformed data. Data are presented for both the year 1991 and year 2000 results. In a ten percent sample the blood lead levels were also compared between the ESA Lead Care instrument and the atomic absorption spectrometry instrument maintained by the Kansas Health and Environmental Laboratory at KDHE. Because of the relatively small number of comparisons, this check for quality assurance utilized the Spearman Rank correlation.

Multivariate analysis of year 2000 data consisted of a multiple linear regression model constructed so that the environmental and behavioral variables were treated as independent variables and the blood lead level was treated as the dependent variable. Modeling was utilized so that any variable that was significant at the alpha = 0.10 level in preliminary analyses was entered for potential selection into the final model. This final model was fit using a stepwise selection process that added and removed variables depending on their adjusted contribution to the overall level of blood lead. The final model contained only those independent variables that were statistically significant at the alpha = 0.05 level. Since some houses had multiple children in the sample, we used an analysis weighted by the number of children in a house. This was done using the house ID variable as a random effect in a mixed effects linear model.

While some comparisons are presented between 1991 and year 2000 results, it should be noted that the methods used in the two surveys were different. The earlier study was a random sample of all families based on a door-to-door survey, and included children, youth, and adults. Environmental data was based on a random sample of homes of all target area residences. The more recent survey was a random sample based on a mail-out and only included families with children less than six years of age. Data from the earlier study were obtained from the previous publication (ATSDR, 1996). The raw data tapes were not accessible. These differences in methods make comparisons between the two surveys inexact. Comparisons between them should, therefore, be treated with considerable caution.

RESULTS

Recruitment forms were mailed to 1,500 addresses. It was determined by post office return comments that 137 of these houses were vacant. Of the remaining 1,363 houses, returns were obtained from 283 (20.8 percent). Of these 283, the number of houses with families who met age and residency criteria for inclusion in the study was 68 (24.0 percent). Of these 68, the number of houses with families willing to participate was

57 (83.8 percent). These 57 houses or families had 70 children. An additional 15 families with 30 children volunteered at the community clinic in Galena instead of by mail. All families met the residency criteria and had received the recruitment forms. However some responded to the mailed forms in person, rather than by mail.

Thus, a total of 100 children from 72 homes were included in the study. According to the U.S. census for 2000 and according to the local school district, there are about 300 children in Galena age 6 to 72 months. Thus, these 100 included children represent about one-third of all Galena children in this age group.

Reasons for the 11 eligible families (or houses) not participating in the study were as follows: 1) six declined (child tested, n=2; not interested, n=2; moved, n=1; busy, n=1); and 2) five could not be reached (after multiple attempts either by phone or by visiting the residence).

In comparing results from the Lead Care instrument to the laboratory values from KDHE, the correlation coefficient for 8 Lead Care and 8 KHEL values (all KHEL values except <1.0) for blood lead was 0.922, p=0.0011 (Spearman).

Table 1 shows 1991 and 2000 survey data stratified by the number of participants, gender, education level, annual income, and year of home construction. Individual data is shown for the first two variables and household data is shown for the remaining three variables. The 1991 data on education, income, and year house built is based on all participants from Galena, not just households with children in them. The number of children participating in the year 2000 increased from 67 to 100. Those included with the head of household having less than a high school education dropped from 20.4 to 2.9 percent. Those in the highest income bracket increased from 0.0 to 27.9 percent. The group surveyed in the year 2000 clearly has a higher distribution of education and income. In 2000 information was provided on the year the house was built for 81 children by means of the questionnaire. Information on the houses of 19 children was not provided.

Table 2 shows 1991 and 2000 data for environmental lead levels (soil, dust, and paint). The 1991 data are from a random sample of homes of children, youths, and adults in Galena. The year 2000 data are from all homes of all the children in the study. The mean soil level of lead has decreased 9.7 percent (from 299 to 270 mg/kg) while the mean dust lead level is down 2.8 percent (from 181 to 176 mg/kg). The mean lead value in paint has increased from 0.58 to 1.68 mg/cm^2 (191.4 percent). On the other hand, maximum values of soil lead have increased 318.4 percent and maximum values of dust lead have increased 9,319.3 percent. Maximum values of paint lead have increased 49.7 percent.

Although not shown, the geometric mean soil lead level in the year 2000 was 194.1 mg/kg in remediated yards, 308.0 mg/kg in not remediated yards, and 479.7 mg/kg in yards where the remediation status was unknown. The differences are not statistically significant (p=0.18 for a three-way comparison, p=0.17 for a two level comparison of yes/no) and are mostly below levels of concern for high contact play area or bare soils in Kansas. Current regulations specify levels of concern at 400 ppm (or 400 mg/kg) or higher in yard or other areas where child contact is likely and 2,000 ppm or higher in bare soil areas where child contact is not likely.

Table 3 shows 1991 and 2000 data on blood lead levels. Note that the 1991 mean lead level in children for Galena is based on 54 individuals. Data on the remaining 13 children in Galena, as well as data on 9 children from the control area, is missing. Nonetheless, using the data available, the mean blood lead level in Galena is down 45.7 percent, from 4.22 to 2.29 µg/dL. This latter value for Galena is less than that in the control area in 1991 (3.13 µg/dL). Comparable data for children under age six for the U.S. in 1991-1994 would be 2.7µg/dL and in 1999 would be 2.0 µg/dL (MMWR, 1997 and 2000). This represents a decrease of 25.9 percent for the U.S.

Table 4 shows the distributions and percentages of blood lead levels in 1991 and 2000. In 1991, data from 10 children is apparently missing. As presented in 1991, 10.5 percent of samples (6 out of 57) equaled or exceeded 10 µg/dL. In 2000, the comparable percentage is 6.0 percent (6 out of 100). The difference is not statistically significantly different (p=0.36, Fisher's Exact test). Because of differences in the detectable levels between the two years, an additional comparison is made for readings equal to or greater than 5.0 µg/dL. This cutoff was used instead of comparing distributions at or above 1.0 or 1.4 µg/dL. The difference between the percent exceedances in 1991 (23 out of 57, or 40.4 percent) and in 2000 (18 out of 100, or 18.0 percent) is statistically significant (p=0.01, Fisher's Exact test). In 1991 the distribution of blood lead levels in the control area (not shown) for <1, 1-4.9, and 5 or greater µg/dL was 2, 100, and 26, respectively.

Table 5 presents 1991 and 2000 survey data utilizing Pearson Product Moment correlation coefficients between blood, soil, dust, and paint lead levels. In 1991, data included children, youths, and adults in Galena. There are five statistically significant correlations in 1991. These are: dust levels of lead and soil lead (r=0.745), paint lead and soil lead (r=0.694), dust lead and blood lead (0.67), paint lead and dust lead (0.564), and soil lead and blood lead (0.485). In 2000 there is only one statistically significant correlation. This is between paint lead and dust lead (0.470). The correlation between soil lead and blood lead has decreased from 0.485 to 0.129. For dust lead and blood lead the correlation has decreased from 0.67 to 0.078. For paint lead and blood lead the correlation has decreased from 0.29 to –0.096.

Table 6 presents results for questionnaire and some environmental data in 1991 and 2000. Data are weighted by the number of children per household. Data from 1991 included information for children from both Galena and the control area. In the year 2000 information was provided on age of house construction for 71 out of 72 houses. There are other places where data were not complete in the year 2000 (e.g., information on swallowing non-food items was not available for two out of 100 children and 12 of the 100 children lived in homes with an unknown yard remediation status). In the year 2000 significant results in blood lead levels (µg/dL) are seen for sex (male= 2.77, female=1.92, p=0.04), age group (2-6=2.55, <2=1.64, p=0.05), mouths furniture (yes=3.89, no=1.88, p=0.00), and swallows non-food items yes=5.96, no=2.04, p=0.00). In 1991 significant results were found for annual income less than $15,000, no air conditioning, and house older than 1940. These categories were not significantly different in 2000.

Results for yard remediation are the opposite of what one would expect, with blood lead levels non-statistically significant in 43 children with remediated yards than in the 45 non-remediated yards (2.42 µg/dL versus 1.90 µg/dL, p=0.20). Results for blood lead levels were higher in 43 children with remediated yards. For 12 yards remediation status was unknown, possibly due to the 911 address change. There were also no significant differences in mean blood lead levels across all three groups of remediated yards. For the six children whose blood lead levels were elevated above 10 µg/dL, two of them lived in homes with remediated yards, one lived in a home without a remediated yard, and three lived in homes whose remediation status is unknown (data not shown).

Table 7 presents the weighted multivariate analysis for the year 2000. One house was dropped in the analysis (out of 72) because it did not answer one question concerning swallowing non-food items. The results show that there are five statistically significant ($p<0.05$) predictors of increased blood lead. These include mouths furniture, male sex, does not have air conditioning, log max soil, and swallows non-food items. The strongest predictor is mouths furniture ($p < 0.0001$). Although yard remediation was entered into the model it did not show up as a statistically significant predictor of blood lead levels (p=0.59 for yes or no remediated yards). A different multivariate analysis was used in the 1991 study (Principal Components Analysis) and so the exact magnitudes of those results are not directly comparable to these results. However, a statistically significant increase in risk for elevated blood lead levels for children was shown in the earlier study for those: 1) living in Galena, 2) where the head of household had less than a high school education, 3) where the annual household income was less than $15,000, 4) where a smoker resided in the home, 5) who were male, 6) with an absence of air-conditioning in the home, and 6) who lived in a home built before 1940.

Figure 2 shows sectors of Galena where 0, 1, or 2 children per area had elevated blood lead level test results. Four of the five areas with children with elevated blood lead levels are to the west or south of the center of town. Prevailing winds are generally from the southwest and so these areas are generally upwind of the old smelter site and downwind from Oklahoma. One area lies downwind of the old smelter site. However, since the underlying population of children is not presented in the figure, and thus rates are not presented, the information should be considered as illustrative and not indicative of a specific risk of elevated blood lead levels.

DISCUSSION

The results indicate that despite all the remediation efforts there has been remarkably little improvement in overall soil or dust levels of lead. While geometric mean values have decreased slightly, there has been a marked increase over time in the maximum levels. There is a non-statistically significant reduction in soil lead levels in remediated yards. Paint lead values have actually increased. There has been a decrease in the relationship of blood lead with soil lead levels. In addition, there has been an overall significant decrease in blood lead levels. However, blood lead levels in the U.S. as a whole are estimated to have decreased about 32.0 percent during the period 1991 – 2000 (3.2 percent per year). Thus, one might hypothesize that, by comparing 45.7 (Table 3) to 32 percent, the maximum reduction in mean blood lead levels in Galena that could be attributable to lead dust control is perhaps about 13 percent. It is recognized that this estimate is based on extrapolating from two data points and it is inconsistent with the results for the lack of change in lead levels in environmental media.

The year 2000 survey indicates that the major predictors for an increased blood lead level in children are mouths furniture, male sex, no air conditioning in the home, the log max soil lead level, and swallowing non-food items. This suggests the importance of behavioral and environmental factors at work.

Unfortunately there was no control area chosen for analysis in the year 2000 and thus the analysis is forced to rely on a comparison to U.S. data on trends in blood lead levels. This background change is estimated to be about 32 percent over the 1991-2000 time period (MMWR, 2000). However, Galena children living in houses with yards that were remediated showed a smaller reduction in blood lead levels, a totally unexpected result. Possibly either the original cleanup was not sufficient, the cleanup was sufficient at the time but the area has been re-contaminated from mine waste dust transported by the wind from elsewhere, the weathering and/or deterioration of interior and exterior surfaces, or some unknown factor. Further research could explore these issues (e.g. speciation of lead). The soil remediation value of 800 ppm was used as a site specific number developed for the Tri-State area and was chosen in consideration of the additional components of the remedy (i.e., health education and institutional controls).

Although associations of blood lead levels with environmental lead exposure have declined, there still is - from the multivariate analysis - some significant relationship with soil lead levels. Thus, despite the improvement shown in the univariate and bivariate analysis, there would appear to be room for improvement insofar as soil lead levels are concerned.

This was a cross-sectional prevalence study, conducted nine years after the original. Thus, the 57 children included in the 1991 survey are outside the age limits of this repeat survey and are therefore not included in the group of 100 surveyed herein. The changes in blood lead levels are in different individuals. Not all the 72 houses included in the 2000 study were present in 1991. Migration patterns are unknown.

The families surveyed also differed in their income and educational levels between 1991 and 2000. These differences could also have affected the difference in the relationship of the variables between the two surveys.

Differences in selection of study subjects, in inclusion of a wider age distribution in the 1991 data set, and our inability to obtain the raw data set from 1991, effects the comparison of the data sets from the two time periods. The magnitude of this difference between the two data sets is uncertain but should be considered in interpretation of the results.

The 2000 study used the anodic stripping voltammetery (ASV) method, with positives confirmed by graphite furnace atomic spectroscopy (GFAAS). ASV is a CDC approved analytic method. The 1991 study used GFAAS methodology, per established CDC protocol. The ASV method has a higher lead detection limit than the GFAAS method used in the 1991 study. The ASV method was used in 2000 as it was established protocol for Cherokee County Health Department and a CDC approved analytic method.

The strengths of the year 2000 study include good validity for the environmental and blood lead levels. The questionnaire was the same one as used in 1991, thus insuring comparability. The 60-day residency requirement insured that there was a reasonable time for exposure to the Galena environment and was also similar to the method used in the 1991 survey. This was an intensive interview about potential risk factors. The study also included a reasonably large sample of children living in Galena.

Weaknesses of the year 2000 study include the lack of a control town, the use of a different, yet equal, analytic method for the biological specimen collection and analysis, the use of a mailed out approach for sample selection instead of a door to door approach (used in 1991), the lack of information on the non-respondents to the mailed out recruitment form, and the lack of information on those refusing the request for participation made to eligible residents. Regarding the discrepancy in the collection of 1991 and 2000 sample of homes, the children of non-respondents and/or non-participants could have different blood lead levels than children of participants. The large number of vacant address returns in 2000 could be related to the 911 address change in the time period between the two surveys.

CONCLUSIONS AND RECOMMENDATIONS

In conclusion, based on national data, blood lead levels have apparently decreased more than expected. No significant changes were found in soil or paint lead levels. The percent of children exceeding normal levels of blood lead decreased slightly. The soil remediation component used for this site was apparently only somewhat effective; there still is some effect of soil lead levels on blood lead levels. However, the educational component was probably effective in reducing average blood lead levels.

A risk may exist for those children with a predisposition for soil pica who live in homes with yards with elevated soil lead levels.

Further education of the public is needed to help prevent children from mouthing furniture and from putting non-food items in their mouths. As timeliness is important, parents should review previously distributed packets on lead poisoning prevention. Other immediate steps that can be taken include wet mopping of floors and wet wiping of windowsills. Air conditioning units should be recommended for the citizens in this area.

The results indicate that lead based paint was a significant factor predicting dust lead levels in the year 2000.

The city should apply for a HUD Lead Hazard Remediation grant or other federal assistance to address the lead based paint hazards. Further soil remediation may also be required. Further research needs identified by this study include following up those children with elevated blood lead levels to see their outcome in school. This could be done in conjunction with the ongoing study in Missouri to increase the sample size. An opportunity to do this with children with elevated blood lead levels in the 1991 surveys in Kansas and Missouri was missed. Additional homes should be tested for lead contamination and remediated, regardless of whether the source is internal or external to the house. It is very difficult, if not impossible to separate house dust from soil lead levels in this area given the overall contamination of the area and the natural ventilation of the local homes.

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TABLES

Table 1—Demographic Data for Galena, Kansas. 1991 and 2000 Survey (percent).

Data		1991	2000
Number	Participants	167	100
	Eligible Children	246	300[a]
	Participating Households	57	72
	Participating Children	67	100
Gender	Males	32	48
	Females	35	52
Education of Head[b] of Household	Less than High School	34 (20.4)	2 (2.9)
	High School Graduate	77 (46.1)	45 (64.3)
	College/Technical School	47 (28.1)	22 (31.4)
	Graduate School	9 (5.4)	1 (1.4)
Annual Income[b]	Less than $15,000	58 (50.9)	24 (35.3)
	$15,000-24,999	24 (21.0)	13 (19.1)
	$25,000-34,999	32 (28.1)	12 (17.6)
	$35,000 or greater	0 (0.0)	19 (27.9)
Year House Built[b]	Before 1940	63 (46.0)	18 (31.6)
	1940-1979	34 (24.8)	27 (47.4)
	1980 or later	40 (29.2)	12 (21.0)

[a] An approximation based on U.S. census data.
[b] Data from 1991 is for households of children, youths, and adults in Galena.

Table 2—Natural Log and Geometric Mean Environmental Lead Levels, Galena, Kansas. 1991 and 2000 Survey.

Media	1991[a]					2000				
	N	Mean	SD	Min.	Max.	N	Mean	SD	Min.	Max.
Soil (mg/kg)	30	5.7 (299)	0.97	3.9 (49.4)	7.77 (2,368)	72	5.6 (270)	1.15	3.23 (25.4)	9.2 (9,907)
Dust (mg/kg)	30	5.2 (181)	0.86	3.7 (40.4)	7.11 (1,229)	72	5.17 (176)	4.44	-6.91 (0.001)	11.66 (115,763)
Paint (mg/cm^2)	27	-0.54 (0.58)	0.99	-1.2 (0.30)	1.9 (6.68)	72	0.52 (1.69)	1.42	-1.61 (0.20)	2.3 (10.0)
Values are computed using log-transformed data. Geometric means are given in parentheses.										

[a] Data from 1991 is based upon a random sample of homes of children, youths, and adults in Galena.

Table 3—Natural Log and Geometric Mean Blood Lead Levels (µg/dL) in Children Less than Age 6 in Galena, Kansas. 1991 and 2000 Survey.

Community	1991[a]			2000		
	N	Mean	SD	N	Mean	SD
Galena	54	1.44 (4.22)	0.75	100	0.83 (2.29)	0.92
Control Area	128	1.14 (3.13)	0.53	-	-	-
Values are computed using log-transformed data. Geometric means are given in parentheses.						

[a] Data from 1991 indicates 13 missing blood lead values from individuals in Galena and 9 missing blood lead values from individuals in the control area.

Table 4—Distribution of Blood Lead Levels (μg/dL) in Galena, Kansas. 1991 and 2000 Survey.

1991[a]		2000	
Lead Level	N (%)	Lead Level	N (%)
<1.0	3 (5.3)	<1.4	30 (30.0)
1-4.9	31 (54.4)	1.4-4.9[b]	52 (52.0)
5-9.9	17 (29.8)	5-9.9	12 (12.0)
10-14.9	5 (8.8)	10-14.9	4 (4.0)
15-19.9	0 (0.0)	15-19.9	1 (1.0)
20-24.9	0 (0.0)	20-24.9	1 (1.0)
25 or greater	1 (1.8)	25 or greater	0 (0.0)
Total	57	Total	100

[a] Data from 1991 indicates 10 missing blood lead values from individuals in Galena.
[b] Detection limit for blood lead levels was 1.0 μg/dL in the 1991 survey and 1.4 μg/dL in the 2000 survey.

Table 5—Correlation (r) Between Blood and Environmental Lead Levels, Galena, Kansas. 1991 and 2000 Survey.

		1991[a]			2000		
Variable	Correlated With	N	r	p value	N	r	p value
Soil	Blood	30	0.485	0.01	72	0.129	0.2810
Dust	Blood	30	0.67	0.0001	72	0.078	0.5131
	Soil	35	0.745	< 0.01	72	0.219	0.0644
Paint	Blood	30	0.29	0.13	72	-0.096	0.4230
	Soil	31	0.694	0.0001	72	0.143	0.2296
	Dust	31	0.564	0.0009	72	0.470	< 0.0001

[a] Data from 1991 included homes of children, youths, and adults in Galena.

Table 6—Natural Log and Geometric Mean Blood Lead Levels by Selected Demographic, Behavioral, and Environmental Variables, Galena, Kansas[a]. 1991 and 2000 Survey.

	1991[b]				2000			
Variable	N	Mean	SD	p value	N	Mean	SD	p value
Income								
< $15K	35	1.22 (3.39)	0.68	< 0.00	34	0.88 (2.41)	0.99	0.82
≥ $15K	86	0.65 (1.92)	0.67		60	0.79 (2.20)	0.86	
Education								
≤ H.S. degree	53	0.83 (2.29)	0.55	0.45	67	0.90 (2.46)	0.92	0.19
College/Tech	64	0.73 (2.07)	0.78		30	0.61 (1.84)	0.82	
Air conditioning								
Yes	109	0.72 (2.05)	0.65	< 0.00	95	0.80 (2.23)	0.90	0.31
No	27	1.33 (3.78)	0.67		5	1.38 (3.96)	1.12	
Gender								
Male	75	0.91 (2.48)	0.63	0.27	48	1.02 (2.77)	0.87	0.04
Female	61	0.77 (2.16)	0.76		52	0.65 (1.92)	0.93	
Year house built								
< 1940	35	1.33 (2.16)	0.68	< 0.00	23	0.85 (2.33)	0.82	0.68
≥ 1940	87	0.68 (1.97)	0.61		58	0.69 (1.99)	0.92	

Table 6— (Con't.)

	1991[b]				2000			
Variable	N	Mean	SD	p value	N	Mean	SD	p value
Age								
Age < 2	-	-	-	-	24	0.49 (1.64)	0.78	0.05
Age 2-6	-	-	-		76	0.94 (2.55)	0.94	
Mouths furniture								
Yes	2	1.37 (3.93)	0.09	0.28	27	1.36 (3.89)	0.79	0.00
No	134	0.84 (2.32)	0.70		73	0.63 (1.88)	0.89	
Swallows non-food items								
Yes	5	0.94 (2.56)	0.27	0.77	8	1.79 (5.96)	0.74	0.00
No	131	0.84 (2.32)	0.71		90	0.71 (2.04)	0.86	
Has pets								
Yes	-	-	-	-	42	1.12 (3.07)	0.98	0.06
No	-	-	-		58	0.62 (1.85)	0.81	
Paint condition								
Intact	-	-	-	-	72	0.72 (2.06)	0.91	0.15
Fair or poor condition	-	-	-		28	1.10 (3.01)	0.89	

Table 6— (Con't.)

	1991[b]				2000			
Variable	N	Mean	SD	p value	N	Mean	SD	p value
Yard remediated								
Yes	-	-	-	-	43	0.88 (2.42)	0.87	0.20[c]
No	-	-	-		45	0.64 (1.90)	0.88	
Unknown	-	-	-		12	1.34 (3.80)	1.05	
Values are computed using log-transformed data. Geometric means are given in parentheses.								

[a] Household variables (income, education, air conditioning, year house built, has pets, paint condition, and yard remediated) are weighted by the number of children per household.
[b] Data from 1991 included information for as many as 54 children from Galena and 128 children from the control area.
[c] p value comparing remediated to not remediated.

Table 7—Weighted Multiple Linear Regression of Blood Lead Levels and Selected Independent Variables, Galena, Kansas[a,b]. 2000 Survey.

Effect	β – Coefficient	Std Error of β	T Statistic	P - Value
Intercept	-0.7064	0.4446	-1.59	0.1174
Mouths furniture	0.8209	0.1860	4.41	< 0.0001
Male sex	0.3811	0.1499	2.54	0.0129
Does not have air conditioning	0.8763	0.3709	2.36	0.0212
Log max soil	0.1752	0.0743	2.36	0.0217
Swallows non-food items	0.6179	0.2866	2.16	0.0339

[a] In addition to the above independent variables, household ID was also entered into the model as a random effect in order to adjust for the correlation between children from the same household.
[b] Based on data from 71 out of 72 households.

FIGURES

Figure 1—Location of Galena, Kansas

Figure 2—Areas with elevated blood lead levels of children ages 6 to 72 months. Galena, Kansas, 2000 Survey.

APPENDICES

Appendix 1—Household Census Form

Appendix 2—Consent Forms

Appendix 3—Questionnaire

Appendix 4—Blood Sampling Protocol

Appendix 5—Sample Blood Lead Result Letters

Appendix 6—Sample Environmental Results Letters

Appendix 7—Chain of Custody Form

Appendix 8—Environmental Sampling Protocols

Appendix 9—Environmental Sampling Forms

Appendix 10—Clinical Review of Lead Care Instrument