FINAL REPORT

Health Studies at the Tar Creek, Oklahoma Superfund Site

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Introduction

The Tri-State Mining District of Kansas, Missouri, and Oklahoma was created in the latter half of the 19th. Century. The district was a major supplier of zinc and lead until the early 1970's, when the last of the mines were closed (ATSDR 1996, Missouri Department of Health 1995). Remaining today are sinkholes, floatation ponds, and mine tailings. Floatation ponds are where much of the residual fine particles of mine wastes may be found. The Oklahoma portion of the district comprises about 40 square miles in Ottawa County (ATSDR 1993). Because of community concerns about the potential health effects from the mine wastes at the Tar Creek, Oklahoma subsite of the overall Superfund Site, this report was commissioned through the Local Environmental Action Demanded (LEAD) Agency, Inc., and funded by a U.S. Environmental Protection Agency Technical Assistance Grant.

In order to evaluate the situation more completely a brief review of the health and environmental problems in the Kansas portion of the Tri-State Mining District seems in order. All three contiguous counties in these three states have similar environmental degradation issues. However, Ottawa County, Oklahoma has been more environmentally degraded than the other two (Cherokee County, Kansas and Jasper County, Missouri).

The author was originally involved in investigating cancer mortality in counties of Missouri, Iowa, Nebraska, and Kansas. The project was funded by the Region 7 office of the U.S. Environmental Protection Agency (EPA). An excess of lung cancer was found, with an excess in white males in 1973-1977. All three counties in Kansas, Missouri, and Oklahoma combined had elevated mortality rates compared to the U.S. average (78.4 versus 62.3 deaths per 100,000 population). Lung cancer excess in white females was also elevated in Cherokee County compared to the U.S. average (19.5 versus 15.2 per 100,000) and this rate was increasing more rapidly than expected. No other cancer death rates were elevated in the Tri-State Mining District area (Neuberger 1982, 1983).

As a result of that research the author suggested that, because of the excess lung cancer mortality in the Tri-State region, coupled with the obvious evidence of mining activity, that the EPA investigate this area more completely. The area was subsequently declared a Superfund site largely due to the presence of lead in the mine wastes and tailings. Up to 3,800 ppm of lead was found in Cherokee County, Kansas. Areas in Galena, Kansas and Jasper County, Missouri were subsequently remediated by the EPA (EPA 1997, ATSDR 1993). The action levels were 800 ppm in Kansas and Missouri and 500 ppm in Oklahoma.

Subsequent research on the excess lung cancer in Cherokee County found that 35 out of 36 male cases and 10 out of 11 female cases had smoked. For male cases average pack-years (one pack-year is smoking one pack of cigarettes for one year) were 62.3 (engaged in mining) versus 86.0 (those who did not). Risks from cigarette smoking were somewhat elevated, particularly for females. The odds-ratio (OR), or risk of exposure among those with lung cancer versus the risk of exposure among those without lung cancer, was 14.8 and 18.0 for ever smoking males and females, respectively. For males an increased risk

was found for exposure to the underground lead-zinc mines in Picher-Cardin (odds-ratio=5.1), with exposure to dusts and 50 pico-Curies per liter of radon (Neuberger 1983).

Other health problems found in the Tri-State Mining District over time included tuberculosis, silicosis, and pneumoconiosis. These were also largely due to mining operations. In additional research conducted in Cherokee County, there were a statistically significant excess of deaths in Cherokee County (compared to U.S.) during 1959-1981 from heart disease (20 percent increase), stroke (30 percent increase), pneumoconioses (2,000 percent increase), kidney disease (50 percent increase), and accidents (40 percent increase) (Neuberger 1990).

In research focused on Galena, for five or more year residents of Galena (compared to two control towns) there was a statistically significant increase in the prevalence of chronic kidney disease (females 65+), heart disease (females 65+) (two-fold excess), and anemia (females 65+) during 1980-1985. For all three cities there were statistically significant relationships between diseases and various residency factors related to Galena. Diseases included stroke, chronic kidney disease, hypertension, heart disease, skin cancer, and anemia. Exposures included the smelter, mine tailings, private well water use, and length of residence. Comparing Galena to the rest of Cherokee County, and using mortality rates from 1980-1985, the rates in Galena were statistically significantly elevated for females in several disease and age categories. Cerebrovascular disease (214.8 versus 8.2 per 100,000 in age group 45-64) and hypertensive disease (262.5 versus 42.6 per 100,000 in age group 65+) were both elevated (Neuberger 1990).

Relationship(s) between the preceding complex health problems, occupation, environment, and lifestyle were not clear. Further study was considered warranted, but there was no follow-up study.

At about the same time that the above lung cancer study was reported, concern was expressed in the Oklahoma portion of the district about the contaminated ground and surface water due to the acid mine runoff stemming from the closed underground mines. While the original concern in Oklahoma was related to water quality, in Kansas the concern related to health effects, particularly lung cancer, heart disease, and stroke. Health effects in the Oklahoma portion of the district have now reached a level of interest where the local citizens have asked for an assessment of the situation.

In order to reflect more globally on potential health problems related to the Tar Creek Superfund site, this research was commissioned. In order to respond to community interest two questions were asked: 1) Given existing data, is there any evidence of a health problem (or problems) that could possibly be related to residence at the Tar Creek (Oklahoma) Superfund Site, and 2) What, if any, additional health studies might be needed to more definitely answer this question?

Methods

A preliminary meeting was held in Miami, Oklahoma with citizens interested in the health study project. The purpose was to see what their health concerns were. Subsequently, additional meetings were held with the leadership group of the LEAD Agency, with lay advisors of Tribal Efforts Against Lead (TEAL), and a citizen's group to further discuss the approach to be utilized. A field trip was taken to review the situation on the ground. The Superintendent of Schools in Picher-Cardin had expressed concern about math scores in his district. Thus, attention was focused on this outcome.

A literature review was conducted of Federal and Oklahoma State publications concerning the Tar Creek site. In addition, Federal and State publications dealing with other mining waste Superfund Sites were included. Peer reviewed scientific publications were also reviewed, as was the protocol of an ongoing study. Information regarding unfunded grant proposals was obtained.

Additional data collection and analysis were also performed. Observed mortality in the county was compared to expected mortality for relevant conditions. These health conditions included lung cancer, bronchitis, emphysema, and asthma, heart disease, hypertension, stroke, and kidney disease. Low birth-weight rates were obtained from the Oklahoma State birth records.

Death and birth certificate information were obtained for the state and county for the period 1999-2001 from the Oklahoma State Department of Health. Low birth weight was reported for infants weighing <2500 grams. Infant mortality was recorded as total deaths in children under the age of one. Major causes of death were calculated using age adjustment of 10 age strata (0-4, 5-14, 15-24, 25-34, 35-44, 45-54, 55-64, 65-74, 75-84, and 85 and over). Deaths were grouped based on the ICD-10 classifications. Population numbers were obtained for the county from the year 2000 U.S. Census. County data (observed versus expected) were compared to the State. All races and both sexes were combined in the analysis. A Standardized Mortality Ratio (SMR) was calculated, which was the observed number of events or deaths divided by the expected number of events or deaths times 100 [An SMR of 100 means that the observed number of events or deaths equals the expected number of cases or events. If more events or deaths are observed than expected the SMR will be greater than 100. Conversely, if fewer events or deaths are observed than expected the SMR will be less than 100]. A Poisson statistical test was conducted for 80 or fewer events. For more than 80 events special equations were used (Breslow and Day, 1987; Washington State Department of Health, 2003). The results were reported as statistically significant if the p value was <0.05.

Prevalence rates for a variety of conditions and risk factors were obtained from the Oklahoma State Behavioral Risk Factor Surveillance Survey (BRFSS), conducted by the State of Oklahoma Department of Health. The BRFSS was used to provide information from a population weighted random sample of the adult population (non-institutionalized and age 18 and over) in Ottawa County and the state. The survey was conducted during

2001-2002. The analysis combined both sexes and all races. The results for Ottawa County were compared to that of the State.

Consultations were obtained with health professionals in Oklahoma, Kansas, and Massachusetts. These included representatives of the Oklahoma Department of Health, the Oklahoma Department of Environmental Quality, the Mid-America Poison Control Center at the University of Kansas Medical Center, and the Harvard School of Public Health.

Results

The citizens' meeting revealed concerns with a number of issues, including math scores, cancers, learning disabilities, pulmonary disease, mental disorders, and stroke. The concerns were evaluated and those that seemed to be possible outcomes for the exposures at Tar Creek were considered further, if feasible.

The results of the literature review were divided into environmental levels of lead, environmental levels of cadmium, and environmental levels of silicon dioxide, biological exposures in children and adults, and health outcomes in children and adults. While lead is of primary concern by EPA at the Tar Creek site, cadmium is also a potential health problem. Silicon dioxide would only be a problem through the airborne route of exposure.

With respect to environmental levels of lead, levels of soil lead in nearby Kansas subsites were 1,600 ppm (max.) in mine waste (locally known as chat) and 13,000 ppm (max.) in fine mine tailings (locally known as floatation ponds) (ATSDR 1997). In Oklahoma, twenty-eight high-access areas were sampled in the five mining communities. In 18 areas that were elevated above 500 ppm, the levels of soil lead were as high as 10,800 ppm. In a sample of 2,055 homes at Tar Creek in the mid-90's, 65% had soil lead concentrations greater than 500 ppm (EPA 1997). There were many elevations of soil lead in schools and parks (ATSDR 1995).

From May through August 1995 air sampling was done during fourteen 24-hour periods at five locations around Picher and at a background station. Measurements were made of Total Suspended Particulates (TSP) and Particulate Matter less than 10 microns (PM_{10}). The average downwind measurement concentrations were 51.60 for TSP, 33.96 for PM_{10}, and 0.047:g/m^3 for atmospheric lead. This compares to 0.012:g/m^3 for atmospheric lead at the upwind site, and to a range of 0.0046 to 1.1 :g/m^3 in the U.S. (EPA 1997, Ecology and Environment 1996). However, the U.S. National Ambient Air Quality Standard for inorganic lead is 1.5 :g/m^3 (maximum quarterly average). Thus, the readings obtained for lead were below the standard.

Ten public water supply wells were sampled on a monthly basis for six months. Seven of the 10 were contaminated by mine water (USGS 1995). Cadmium was found in two samples slightly in excess of EPA's Maximum Contaminant Level, while lead was detected in two samples but not above the EPA action level. The town of Picher's water

supply contained elevated levels of metals in 1985. An alternative water supply was established (ATSDR 1993). In 1994 two private water wells were tested for lead in homes of children with elevated blood lead levels; lead was not detected in either sample. No other data were found regarding lead in private water supply wells (ATSDR 1995).

In summary, significantly elevated levels of inorganic lead were found in soil.

With respect to environmental levels of cadmium, levels of soil cadmium in nearby Kansas subsites were 89 ppm (max.) in chat and 540 ppm (max.) in floatation ponds. In Oklahoma, twenty-eight high-access areas were sampled in the five mining communities. In 7 areas that were elevated above 100 ppm, the levels of soil cadmium were as high as 448 ppm (EPA 1997). There were a number of elevations of soil cadmium in schools and parks (ATSDR 1995).

From May through August 1995 24-hour air sampling was done at five locations around Picher. According to their summary no significantly elevated levels of cadmium were found (EPA 1997, Ecology and Environment 1996).

With respect to environmental levels of silicon dioxide (crystalline silica), no data on airborne silica was found.

Data on biological exposures to lead for children aged six to 72 months revealed the following: In the mid-90's prevalence of elevated blood lead levels > or equal to 10ug/dL was 62.5% in mining towns, with an overall prevalence of 30.5%. In a 1992-1993 survey of 189 Native American children from the Tar Creek area, 35% exceeded a blood lead level of 10µg/dL (ATSDR 1997, EPA 1997). In a July and August 1995 survey of blood lead levels in 230 children in the five mining communities of Picher, Cardin, Commerce, Quapaw, and North Miami, 28.3% had blood lead levels ∃10 :g/dL, with some as high as ∃30:g/dL. The state average was 2.4% (Kegler 2000) and the national average 4.4% (ATSDR 1997) above 10:g/dL. In a fall 1996 survey of Picher, Cardin and Quapaw, 38.3, 62.5, and 13.4% respectively, of children exceeded the blood lead level of 10 µg/dL (EPA 1997). In a sample of 224 children aged one to six in 1997 in northeast Oklahoma, increased risks for blood lead levels were independently statistically significantly elevated as mean floor dust lead and yard soil lead increased (Malcoe et al. 2002).

Prevalence of elevated blood lead levels in children was evaluated for the period 1996-2000. A total of 79,748 tests were performed on 50,927 children under age six years in Oklahoma. Five mining communities and four other cities were included. The most recent blood lead levels and the highest blood lead levels were utilized. Elevated levels for the most recent blood lead test (n=2,055 tests in the county) were 18.18% for Cardin and 16.81% for Picher, respectively. Corresponding figures for the highest blood lead test (n=2,058 tests in the county) were 29.03% in Cardin and 22.65% in Picher. Corresponding figures for the county were 5.35% and 7.14%, respectively (Braggio 2002).

The percentage decline in elevated blood lead levels from 1996-1997 to 1999-2000 was 40.0% or 56.25% in Cardin and 11.92% or 21.69% in Picher, depending on whether the most recent or the highest test were used, respectively. Corresponding figures for the county were 6.43% and 10.70%, respectively (Braggio 2002). No data were presented on biological exposures to cadmium in children.

Potential health problems in children aged six to 72 months from elevated blood lead levels in the range of 10-20 :g/dL are lower IQ scores, decreased attention span, decreased bilateral coordination, hearing deficit, decreased speech and language processing, decreased hemoglobin formation, decreased fine-motor skills, and decreased school performance (ATSDR 1997, Klaassen 1996). However, there were no data found regarding actual health outcomes in children aged six to 72 months.

Data concerning biological exposures in children aged six to 20 years were not found.

The only data found pertinent to health outcomes in children aged six to 20 years were math and other school performance scores for the Picher-Cardin School District and for Ottawa County compared to the State of Oklahoma. Although Ottawa County was in the bottom quartile for the percentage of students scoring satisfactory or above in the 2000-2001 Oklahoma Core Curriculum Test (65%), it was not the lowest ranking county. For the Picher-Cardin School District, in the third grade, using the Iowa Test of Basic Skills, the scores in the exposed district were at the 54^{th} percentile versus the 68^{th} percentile for the State. For the 5^{th} grade, 65% scored at a Satisfactory level or above, compared to 72% for the State. For the 8^{th} grade, 50% scored at a Satisfactory level, compared to 71% for the State. The tests used for the latter two grades were the Oklahoma Core Curriculum Test. There were other districts in the State that scored as low as, or lower than the Picher-Cardin School District. There were no data provided for High School performance for math (Office of Accountability 2002).

Data concerning biological exposures in adults were limited to the testing of 37 pregnant women in 1992-1993 from the five mining communities of Picher, Cardin, Commerce, Quapaw, and North Miami. No elevated blood lead levels were found. No data were found concerning cadmium exposure.

Potential health problems in adults from elevated blood lead levels in the range of 10-30 :g/dL are decreased hemoglobin formation, increased hypertension, and hearing deficit. Potential health problems in adults from elevated cadmium levels include chronic obstructive pulmonary disease and emphysema (respiratory exposure), chronic renal tubular disease, and increased hypertension (ATSDR 1997, 1999, Klaassen 1996, Sullivan 2001). However, there were no data found pertinent to these health outcomes.

Data from the literature review concerning health problems found in adults included excess mortality rates for heart disease, cancer, and stroke in 2001 for Ottawa County compared to the State. However, in 2000 there was no increased mortality rate for heart disease, cancer, or stroke. However, the death rate for chronic obstructive pulmonary

disease was slightly increased in 2000, but not 2001. For both years there were no statistical tests of significance utilized. (Health Care Information Division).

Table 1 illustrates the matrix for measurements of exposure to lead and health outcomes. Ideally, one would want to see data developed for each cell in the matrix indicating whether or not a health outcome was studied as well as an exposure for each age group. As can be seen, this was not the case in Tar Creek. There is very limited data on adult lead exposure and no data at all for cadmium exposure. For health outcomes there is only the school performance data by school district. For adults there is very limited data for total cancers and several other conditions. There is somewhat contradictory data in the published data on health effects for adults in Ottawa County. There is no data presented for any age group concerning an association between an exposure and an outcome.

Data from the independent analysis is shown in Tables 2 through 4. Table 2 shows that there was no increase in the number of babies born with low birth weight in the county compared to the State. There were actually fewer low birth weight babies (94 observed versus 102.13 expected) but the difference was not statistically significant. In addition, there was a reduction in the number of infant mortalities compared to the State. However, the difference (9 observed versus 10.87 expected for all causes) was not statistically significant.

Table 3 presents the results of the overall mortality analysis for the selected causes of death. Although there was a slight excess of lung cancer and bronchitis, emphysema, and asthma, these results were not statistically significant. There were no tuberculosis cases observed. There was no real difference between deaths from kidney disease and hypertension, compared to what would have been expected based on state rates. However, there were a statistically significant excess of deaths from stroke (101 observed versus 83.08 expected) and heart disease (434 observed versus 380.22 expected). The excess amounted to almost 22 percent for stroke (SMR = 121.6).

Table 4 presents the results of the telephone interview from the BRFSS. There was no statistically significant excess of individuals reporting yes to asthma, hypertension, or arthritis. The numbers of those responding yes were small (n=18 for asthma). There was also no statistically significant excess of those complaining of joint pain or swelling. However, there was a statistically significant excess of those who ever smoked 100 or more cigarettes (60.1% versus 43.1%, n=74 yes answers in Ottawa County).

Discussion

Clearly there are exposure problems for lead and cadmium at the Tri-State mining district site, including Tar Creek. Pathways of exposure include ingestion and, possibly, inhalation. There was some contamination of public water wells. There may also be an airborne exposure problem for silica at Tar Creek, but there is no data to support or refute this.

Previous studies indicate health problems in adults living around this site (in Kansas). These problems include lung cancer, hypertension, stroke, and heart disease. However, lung cancer was found to be related to cigarette smoking and exposure to underground lead/zinc mining (with dusts and radon levels as high as 50 pCi/L). There have been no additional studies in Kansas regarding etiology.

There have been blood lead level studies in children in the mining areas of all three states. These studies all indicate elevated blood lead levels. In addition, there have been both educational (Kegler 2000) and environmental remediation based efforts to reduce blood lead levels in children both in Ottawa County and in impacted areas of the other two states. These efforts have been analyzed and determined to be successful in the mining areas in two of the states.

Regarding the mortality analysis, stroke and heart disease stand out. However, there are a small number of deaths in several other categories, thus affecting the statistical analysis; three years of death data may not be enough. There were insufficient data available to compare the exposed cities to the State. Approximately 25% of the deaths were not coded to a specific city. Since data was not available by city it was not possible to do exposure/response analysis for mortality data.

With regard to the Behavioral Risk Factor Surveillance Survey (BRFSS), although smoking was shown to be a problem the questions were not designed for this particular environmental exposure problem. As with the mortality analysis, there was insufficient information available to compare the exposed cities to the State. In addition, due to the small numbers it is not possible to do any age stratification. Other problems using BRFSS include the fact that, because of the high poverty rate in the county (about 20 percent; Health Care Information Division), a number of residents of the county lack a telephone.

Given existing data, is there any evidence of a health problem (or problems) that could possibly be related to residence at the Tar Creek (Oklahoma) Superfund Site?

There is some evidence of health problems, but it is not possible to be certain as to whether they are related to metals exposures at the site (such as lead and stroke), behavioral variables (such as smoking and heart disease), some combination of both, or other risk factors.

Considerable information is available on lead and cadmium in soil. The former clearly is a problem. The oral ingestion route of exposure to lead is clearly established for children. Long-term ambient exposure assessment studies for airborne crystalline silica and lead are missing. Lead speciation studies are missing. These could be helpful in determining the source of lead (i.e., paint versus soil) unless the same source is used for both.

While there have been several cross-sectional blood lead exposure assessment studies in children, no health studies dealing with health outcomes have been found for children using readily available data. For example, there have been no follow-up studies (e.g.,

school performance) in previously identified lead poisoned children to determine health outcome.

There have been excess deaths from stroke and heart disease in Ottawa County. This is consistent with the findings from Galena, in Cherokee County, Kansas. However, there has been no study of stroke or heart disease morbidity or mortality in adults coupled with lead or cadmium exposures at the Tar Creek Superfund Site. There has been an excess of smoking in Ottawa County; possibly this is related to the excess in heart disease and stroke mortality. While there are problems using mortality data (e.g., sensitivity as an indicator of disease and validity of diagnosis), mortality is a widely used form of surveillance.

What, if any, additional health studies might be needed to more definitely answer the above question?

A number of health (or health related) studies would be needed to adequately answer the health questions associated with this site.

Year-round air sampling for heavy metals (e.g., lead and cadmium), crystalline silica, and other airborne particulates, would give a more accurate measure of exposure to toxic agents. Localized readings around specific tailings in dry and windy conditions should be included. Meteorological data should be incorporated into the findings. Additional environmental exposure studies for heavy metals would include both new testing of previously untested private wells and continued testing of previously tested public (municipal) and private wells.

In any new studies it might be helpful to incorporate lead speciation analysis in order to attempt to distinguish between lead in paint and lead in soil. However, if the lead in paint is made from local materials, it may not be feasible to adequately distinguish the two.

Some recommended health studies have been previously mentioned by an Oklahoma governmental task force (Office of the Secretary of Environment 2000). These include: 1) regular screening of Ottawa County children for blood lead levels, 2) use of a Geographic Information System map to co-locate children with elevated blood lead levels with soil lead levels, 3) health outcomes studies in children (e.g., learning disabilities), 4) health studies in adults and adolescents to examine neurological effects, kidney disease, hypertension, hearing loss, cancers, and Alzheimer's and Parkinson's Diseases, and 5) study the health effects of gathering and consuming wild foods.

With regard to measures of biological exposure, the continued monitoring of children's blood lead levels would help determine the effectiveness of the ongoing lead abatement activities. Screening all children under 6 years of age for blood lead levels would be a positive development. Any children with elevated levels could be placed on a map so that Geographic Information Systems technology could be brought to bear on the problem.

A follow-up cohort study of both previously exposed and unexposed children would enable scientific evaluation of outcomes specific to lead absorption (e.g., effects on IQ, school record, verbal and math scores, spatial relations, hearing loss, attention deficit hyperactivity disorder, and learning disabilities). Most of these children would be adults now. A study from Silver Valley, Idaho found that neurological effects from elevated soil lead levels increased as bone lead concentrations increased (ATSDR 1997).

A case/control study of adults with hypertension, stroke, and heart disease would be helpful in evaluating the presence or absence of multiple risk factors for these diseases (i.e., blood and bone lead levels, urinary cadmium, cholesterol, diabetes, body mass index, and smoking).

An enhanced and focused BRFSS study comparing selected illness rates in Ottawa County and the six impacted communities (Cardin, Commerce, Miami, North Miami, Picher, and Quapaw) to the State would be a very useful adjunct to the above activities. A larger sample size could allow for greater information stratified by age. Additional questions could be focused on health problems possibly related to lead or cadmium exposure.

In the past there have been at least three grant proposals submitted by university researchers regarding health problems in the Tri-State Mining District that were not funded. These studies proposed to investigate: 1) lung function in non-smokers in Cherokee County, 2) risk factors for lung cancer, stroke, and other chronic diseases in the Tri-State Mining District, and 3) risk factors for kidney disease at the Tar Creek site. In addition, there was an internal proposal from a government scientist to study immune function; that proposal was not funded either. Information from these studies might have proven valuable in understanding the risk factors for health problems in this region.

A pulmonary function study in a random sample of adult non-smokers (include environmental tobacco smoke and occupation) would help evaluate the impact of any airborne dusts. This would need to be done in conjunction with the aforementioned study of airborne particulate matter. A kidney function study in a random sample of adult non-smokers would help evaluate the impact of cadmium. An immune function study in a random sample of the population would also have merit.

A new study that has been funded will evaluate the effects of lead and manganese on cognitive and behavioral outcomes among infants and adolescents and the role of genes and diet in modifying response to those metals. A birth cohort of 800 will be followed to age two. Further plans are to follow this cohort until adulthood to determine health effects among adults from childhood exposures. While this study should prove informative, it was not designed to study either 1) exposure to lead or cadmium in adults with selected chronic diseases or 2) health outcomes in children who were exposed to high levels of lead or cadmium 15-20 years ago, when environmental levels were higher (Wright).

In conclusion, exposure assessment studies in children have been done and have indicated previously high elevated blood lead levels. More recently, these studies have indicated a decreasing blood lead problem. But these studies have not been followed up with health outcome studies. In addition, there appears to be evidence of current health problems in adults that might be related to residence at the Tar Creek site. However, it is uncertain whether these problems are related to environmental exposures (e.g., lead or other heavy metals), behavioral variables, or both. Adults appear to be at risk for mortality from two causes of death, but the reasons are unknown. An adequate assessment of the contribution of hazardous waste to current chronic disease disability, morbidity, or mortality at this site is not possible at this time. Many opportunities to study these problems exist and have existed, but much time has gone by without such studies occurring. Further research is needed in both children and adults for several health categories to more fully understand the situation.

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Table 1

Published Information Concerning Lead Exposures, Health Outcomes, and their Relationship at the Tar Creek Superfund Site

Age group	Lead exposures only	Health outcomes only	Relationship between exposures and outcomes
6-72 months	Yes	No	No
6-20 years	No	Yes (school)	No
21+ years	Yes (limited)	Yes (limited)	No

Table 2

Health Outcomes in the First Year of Life in Ottawa County, Oklahoma

Cause	Observed	Expected	SMR	Statistically Significant?
Low birth weight*	94	102.13	92.0	No
Infant mortality	9	10.87	82.8	No
Infant mortality excluding infectious diseases	7	9.90	70.7	No

* under 2,500 grams.

Table 3

Selected Mortality Outcomes in Ottawa County, Oklahoma

Cause	Observed	Expected	SMR	Statistically Significant?
Lung cancer	86	79.55	108.1	No
Tuberculosis	0	0.27	0.0	No
Bronchitis, emphysema, and asthma	73	66.34	110.1	No
Kidney disease	17	17.27	98.4	No
Hypertension	16	14.22	112.5	No
Stroke	101	83.08	**121.6**	**Yes**
Heart disease	434	380.22	**114.1**	**Yes**

Table 4

Behavioral Risk Factor Survey Comparing Ottawa County to the State of Oklahoma

Health problem	County % Yes (n)*	State % Yes (n)	Statistically Significant?
Asthma	18.6 (18)	10.7 (1,252)	No
Hypertension	30.6 (20)	28.5 (1,451)	No
Arthritis	30.7 (21)	24.2 (3,108)	No
Joint pain or swelling	48.5 (41)	46.4 (3,413)	No
Smoked 100 or more cigarettes	**60.1** (74)	**43.1** (15,486)	**Yes**

* (n) = number of yes answers.

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