Department of Health and Human Services
ATSDR Agency for Toxic Substances & Disease Registry

PUBLIC HEALTH ASSESSMENT

NATIONAL ZINC COMPANY
BARTLESVILLE, WASHINGTON COUNTY, OKLAHOMA

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Prepared by

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Public Health Service
Agency for Toxic Substances and Disease Registry
Atlanta, Georgia

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Agency for Toxic Substances and Disease Registry, 1825 Century Blvd, Atlanta, GA 30345
Contact CDC: 800-232-4636 / TTY: 888-232-6348

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SUMMARY

The proposed National Zinc Company (NZC) National Priorities List (NPL) Site is located in the City of Bartlesville in Washington and Osage Counties, Oklahoma. The proposed NPL site includes all of the lead- and cadmium-contaminated land within a several mile radius surrounding the Zinc Corporation of America facility. A primary cause of the lead and cadmium soil contamination is the past emissions produced by the NZC and other smelting operations conducted at the current location of the Zinc Corporation of America facility.

Based on the available information, the Agency for Toxic Substances and Disease Registry (ATSDR) concludes that the proposed NZC NPL site is a public health hazard because individuals are being exposed to cadmium, lead, and zinc surface soil contamination at levels that could result in adverse health effects. Children are more likely than adults to ingest surface soil contamination. Blood lead studies have demonstrated that the children living in the area of surface soil contamination have higher blood lead levels than children living outside the area of contamination. Individuals who are exposed to the surface soil contamination may experience proteinuria (i.e., protein in urine, which is evidence of mild kidney damage); decreased metabolism of vitamin D; impaired hearing and growth; and slightly lower IQs. Remediation of the contaminated soils should remove this public health hazard.

Environmental monitoring studies conducted in the past indicate that individuals could have been exposed to cadmium, lead, zinc, and sulfuric acid at levels that could result in adverse health effects. Blood cadmium and blood lead studies conducted in the 1970s revealed that children living near the smelter were exposed to elevated levels of cadmium and lead. Individuals who were exposed in the past to the air emissions from the smelter and to the surface soil contamination could have experienced decreased hemoglobin synthesis, anemia, increased blood pressure, impaired hearing and growth, slightly lower IQs, and encephalopathy. Cadmium air emissions from the historical smelter operations could have increased the risk of developing cancer for lifetime residents of Bartlesville. exposure to sulfuric acid air emissions could have resulted in irritations of the eye, nose, throat, lung, and skin at the time of exposure, but does not pose a current threat to the health of individuals in this area.

Analysis of samples taken from groundwater monitoring wells on and near the Zinc Corporation of America facility indicate that the groundwater contamination found on the facility has not migrated very far. No drinking water wells are known to exist within the area of contamination. Therefore, it is unlikely that any drinking water wells have been contaminated with facility-related metals.

Results of ambient-air monitoring data indicate that the interim dust control measures at the residual piles are preventing significant air emissions. ATSDR scientists are concerned that air emissions from the residual piles at the Zinc Corporation of America could occur whenever the piles are disturbed or the interim measures are not continued.

ATSDR recommends the following actions:

1) Continue to clean up the contaminated soils in residential areas.
2) Continue to control air emissions from the residual piles.
3) Evaluate adverse health outcomes that could be related to past exposures.
4) Conduct a thorough review of all health outcome data bases (i.e., cancer registry, birth defects registry, and birth weight records) as the data becomes available.
5) Educate community members and health professionals on the nature and possible consequences of exposure to contaminants at the proposed NZC NPL site.

BACKGROUND

A. Site Description And History

The proposed National Zinc Company (NZC) National Priorities List (NPL) Site is located in the City of Bartlesville in Washington and Osage Counties, Oklahoma. The proposed NPL site includes all of the lead- and cadmium-contaminated land within a several mile radius surrounding the Zinc Corporation of America facility (see Appendix 1, Figure 1). A primary cause of the lead and cadmium soil contamination is the past emissions produced by the NZC and other previous smelting operations conducted at the current location of the Zinc Corporation of America facility (1).

NZC began operations at the site in 1907, primarily to recover metals such as zinc, cadmium, and lead from industrial materials. NZC used smelting and chemical processing to recover the metals. In addition to the NZC smelter, a vanadium smelter (closed in the mid-1980s) and two other zinc smelters (closed in the 1920's) have operated on the land that presently encompasses the current Zinc Corporation of America facility. Zinc Corporation of America purchased NZC in 1987 and continued recovery operations (1).

The only emission control used by the NZC smelter prior to 1969 was a limited sulfuric acid recovery operation built in 1927. A more efficient acid recovery operation, which greatly reduced the sulfur dioxide emissions, replaced the old sulfuric acid recovery plant in 1969. An electrostatic refining process that replaced the NZC horizontal retort furnaces in 1976 greatly reduced particulate stack emissions (1).

From 1975 through 1985, the community surrounding the former NZC smelter was the subject of five major studies. Baker et al. published "Nationwide Survey of Heavy Metal absorption in Children Living near Primary Copper, Lead, and Zinc Smelters" in the *American Journal of epidemiology* in 1977 (2). The data for this study were collected in 1975. Lead and cadmium levels were determined in 1,744 children, 1-5 years old, living in 19 U.S. towns. Children selected from towns not containing smelters were used as controls. The evaluation included analyses of blood, urine, and hair for metals. The Baker et al. study indicated that children in Bartlesville had the highest mean blood cadmium, hair cadmium, and blood lead levels among those evaluated.

The U.S. Environmental Protection Agency (EPA) and Research Triangle Institute conducted a separate study, "Epidemiological Study Conducted in Populations Living Around Non-ferrous Smelters," in 1977 (3). This study confirmed that blood lead levels in Bartlesville children were above safe levels.

Blood lead studies were conducted by Environmental Consultants Laboratory from September 1977 to December 1979 as a part of a class action law suit against the owners of the National Zinc Smelter (4). Blood samples were obtained from 169 individuals (children and adults) who resided within 1.6 kilometers (approximately 1 mile) of the smelter. This study also confirmed that blood lead levels were high in people living next to the smelter.

Two studies (1979 and 1980) evaluated the soil concentrations of metals in the Bartlesville school yards. Both studies found elevated concentrations of lead and cadmium in surface soil and dust in the school yards and schools (greater than 500 milligrams of lead per kilogram of soil [mg/kg] or greater than 30 mg/kg of cadmium) (5,6).

A 1985 doctoral dissertation by a University of Oklahoma student evaluated the health risks associated with the lead and cadmium environmental contamination of air, water, soil, and paint in the Bartlesville area (4). This study concluded that residents of census tract 0002, directly north of the smelter, had the highest potential for exposure to elevated levels of lead and cadmium. The study also concluded that children within census tract 0002 represented the highest risk group.

In May 1991, the Oklahoma State Department of Health (OSDH) asked the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate the public health threats posed by exposures to metals believed to be in the community surrounding the old NZC smelter (1). ATSDR issued a health consultation for NZC in July 1991. The ATSDR Health Consultation concluded that the lead and cadmium soil concentrations found at schools and residential areas were a potential public health concern. ATSDR recommended that the extent of metal contamination be characterized, biomedical monitoring be considered, and community health education programs be provided to the residents and the local medical community.

In November 1991, EPA began an accelerated cleanup program at the proposed NZC NPL site. The first step in the accelerated cleanup program was characterizing the extent of metal contamination around the former NZC site (Phase I) by taking screening samples within a 36-square-mile area (centered around the former NZC site) (7). One-square-mile grids were formed out of the 36-mile area and at least one surface soil (top three inches of soil) grab sample was taken from each grid. These samples were analyzed for 24 target metal compounds, and the results indicated that lead and cadmium were elevated and warranted more extensive evaluation.

During the Phase II characterization and removal action, EPA took surface samples from 54 high access areas (playgrounds, schools, and day-care centers) (7). The results of these samples indicated that 29 of the 54 candidate high access areas had at least one sample above EPA's action levels established for emergency removal purposes (500 mg/kg for lead and 30 mg/kg for cadmium). In addition to the high access areas, other locations were also sampled to determine the nature and extent of lead and cadmium contamination. These other locations were residences at which elevated blood lead levels were detected in resident children. The results of these two assessments prompted EPA to remove contaminated surface soil from the 25 high access areas and 10 residences.

In August 1992, EPA conducted Phase III of the cleanup program. About 2,000 soil samples from the surface down to 24 inches were collected at specific grid locations to verify the extent of metals contamination across Bartlesville and the surrounding area (8). As part of Phase III, soil samples were collected from yards of 22 residences occupied by children with blood lead levels of 10 micrograms of lead per deciliter of blood (μg/dL) or greater.

While EPA was conducting the Phase I and II site characterization and removal actions, ATSDR funded OSDH (now the Oklahoma Department of Environmental Quality [ODEQ]) to perform blood lead studies (biomedical monitoring) (9). The studies' results indicate that blood lead levels in children are higher in the area where soils contain high levels of lead. A more detailed discussion of the blood lead studies is presented in the Health Outcome Data Evaluation section of this Assessment.

In addition to funding the blood lead studies conducted by OSDH, ATSDR also sponsored a seminar to educate physicians. Dr. Roy DeHart, Director of the Division of Occupational and Environmental Medicine, University of Oklahoma Health Sciences Center, discussed implications of lead exposure when he spoke to about 50 people at the meeting of the Washington County Medical Society February 12, 1992. Also during 1992, Dr. Edd Rhoades, Chief, Child Health and Guidance Services, OSDH, conducted medical education regarding lead exposure to children.

EPA proposed listing the NZC site on the NPL in May 1993 (7). On March 15, 1994, EPA approved the State Pilot Delegation Program (10). The program transferred the administration of the remediation of the site from EPA to ODEQ. This program is being undertaken in lieu of finalizing the NZC site on the NPL. Also on March 15, 1994, ODEQ and the Potentially Responsible Parties (PRPs) signed a Consent Agreement and Final Order.

The Phase III removal action began in March of 1994 (7). This action is being conducted by the PRPs. The removal action will focus on residences with surface soil contamination of greater than 1,500 mg/kg for lead and/or 90 mg/kg for cadmium. These levels are three times EPA's action levels of 500 mg/kg for lead and/or 30 mg/kg for cadmium. As in the initial removals, all soil above the action levels will be excavated in 6-inch increments down to a maximum depth of 24 inches. To date, 263 residential yards have been remediated.

A Remedial Investigation/Feasibility Study (RI/FS) prepared by the PRPs was made available to the public on July 1, 1994. The RI/FS was finalized on September 1, 1994 (11).

On December 13, 1994, ODEQ issued a Record of Decision (ROD) for the first operable unit for the proposed NZC NPL site (10). The first operable unit addresses the portions of the site that are most likely to impact human health. The function of this operable unit is to reduce the risks to human health associated with exposure to the contaminated materials. The major components of the selected remedy outlined in the ROD include:

- removal and disposal of contaminated soils (arsenic concentrations higher than 60 mg/kg, cadmium concentrations higher than 100 mg/kg, or lead concentrations higher than 925 mg/kg) followed by restoration of yards in residential areas;
- implementation of a program to monitor blood lead levels throughout (annually) and after the remedial action (comprehensive studies 2 years and then 5 years after completion of the remedial action) in the affected community; and
- removal, tilling, capping, and/or treatment of contaminated soils (arsenic concentrations higher than 600 mg/kg, cadmium concentrations higher than 200 mg/kg, or lead concentrations higher than 2,000 mg/kg) in commercial and industrial areas.

In the future, ODEQ will issue a ROD for the second operable unit for the proposed NZC NPL site (10). The second operable unit will address any undue risks the site poses to environmental receptors.

In order to address the contamination at the former NZC facility, EPA issued a Resource Conservation and Recovery Act (RCRA) corrective action order on August 26, 1993. The order requires the owners of the Zinc Corporation of America facility to develop and implement a cleanup plan for the environmental (e.g., soil and groundwater) contamination at the facility (12). To date, the owners of the Zinc Corporation of America facility have conducted ambient air monitoring near the residue piles and groundwater monitoring at and near the facility (13,14). In addition, the owners have instituted dust suppression measures at the residue piles and are expediting closure of two surface impoundments at the facility (13).

B. Site Visit

A site visit was conducted by ATSDR staff (Sven E. Rodenbeck and Dr. John Crellin from the Division of Health Assessment and Consultation, Superfund Site Assessment Branch, and Jennifer Lyke and Roberta Erlwein from the ATSDR Region VI Office) on October 26 - 28, 1993, to collect information for the Public Health Assessment for the proposed NZC NPL Site (Update 14). Public Availability Sessions were held on October 27. In addition, meetings were held with EPA; ODEQ; Citizens Against Toxics (CAT), a local citizens' group; the City of Bartlesville; representatives of various other organizations; and other individuals.

The following observations were made during the site visit:

- During the site visit, the Zinc Corporation of America smelter was not operational while modifications to the plant were being conducted and activities associated with the RCRA corrective action order were being implemented.
- The Zinc Corporation of America facility has approximately 77 structures (manufacturing buildings, offices, etc.) and 5 wastewater impoundments. It is totally surrounded by an 8-foot chain-link fence and is patrolled by security guards 24 hours per day. The impoundments are reported to range in size from 10,000 square feet to 687,500 square feet. There are several waste piles at the facility. The largest is a pile of goethite, which may include cadmium, copper, lead, zinc, manganese, cobalt, and iron, and the pile is reported to contain 4 million cubic feet of material.
- The Phillips Research Center is located across State Road 123 directly west of the Zinc Corporation of America facility.

- Most of the contaminated areas are residential areas. Lower cost residential areas are near the smelter.

In addition to a general site survey, the ATSDR staff visited most of the high access areas that have been remediated by EPA.

During the public comment Period (September 21, 1994 through November 20, 1994) for this public health assessment, ATSDR staff (Sven E. Rodenbeck, Dr. John Crellin, and Ms. Jennifer L. Lyke) held a Public Meeting on October 13, 1994. The meeting permitted the public to discuss the public health assessment in an open forum. During the Public Comment Period, comments concerning this public health assessment were given verbally and were submitted in writing. In addition, meetings were held with ODEQ, CAT, and the City of Bartlesville. The public comments along with ATSDR's responses are summarized in Appendix 5.

C. Demographics, Land Use, And Natural Resource Use

1. Demographics

Bartlesville is the county seat for Washington County and has a population of about 46,700. The three major employers in the city are Phillips Petroleum Company, Zinc Corporation of America, and Reda Camco Incorporated (a pump manufacturer). The National Institute for Petroleum Energy Research is also located in Bartlesville.

According to 1990 census data, Washington County's population was approximately 48,800 (91.2 percent white, 2.6 percent black, and 6.2 percent other; 59 percent male and 41 percent female). Children (0-9 years old, 51.4 percent male and 48.6 percent female) made up 14.3 percent of the Washington County population in 1990.

2. Land Use

The largest portion of the land area on the proposed NPL site is residential. Some of the residences have gardens. Three elementary schools and 10 day-care centers are also located within the proposed NPL site. Most of the properties directly bordering the Zinc Corporation of America facility are zoned for industrial use.

Most of the unzoned areas north and west of Bartlesville are used for agricultural purposes. Agricultural products that are commonly grown or raised in the Bartlesville area include beef cattle, horses, hogs, sheep, soybeans, wheat, sorghum, corn, and alfalfa.

The Prairie National Wild Horse Refuge is located a few miles southwest of Bartlesville. It was established in 1989 and covers more than 18,000 acres. A Bison Refuge is north of Bartlesville.

3. Natural Resource Use

Surface runoff from the Zinc Corporation of America facility is primarily towards the south. Two tributaries (North and West) of Eliza Creek collect the surface runoff. These tributaries combine and flow into Eliza Creek approximately 4,000 feet south of the facility. Eliza Creek combines with Sand Creek and they discharge into the Caney River south of the City of Bartlesville. Fishing may be conducted in Eliza and Sand Creek. In addition, the flood plain of Sand Creek is actively mined for sand. The Caney River flows through the center of Bartlesville and is used for recreation and fishing.

Lake Hudson and Lake Hulan, north of the NZC site, supply the Bartlesville drinking water. The lakes are not within the drainage basin of the proposed NPL site. According to EPA, no wells within a three mile radius of the former NZC facility are used for drinking water.

D. Health Outcome Data

ATSDR selects health outcomes for further evaluation from health outcome databases that have information on the area near the site. Oklahoma has a cancer incident registry and a birth defect registry.

Cancer and birth defects could be plausible health outcomes from exposure to lead and cadmium. Please refer to the Toxicologic Evaluation subsection for more detailed information.

In addition to the health databases maintained by OSDH, the National Center for Health Statistics, Centers for Disease Control and Prevention (CDC), maintains vital statistics information (birth and mortality records) for the various counties in the U.S. Mortality statistics were obtained for Washington County for the years 1979 through 1988.

COMMUNITY HEALTH CONCERNS

During the October site visit, the Agency for Toxic Substances and Disease Registry (ATSDR) staff members determined the community health concerns via conversations with local government officials, U.S. Environmental Protection Agency (EPA) officials, Oklahoma Department of Environmental Quality (ODEQ) officials, members of Citizens Against Toxics (CAT), and individual citizens (during the public availability sessions). The residents and officials raised the following health-related concerns:

1. Is the cancer incidence (as the result of occupational and environmental exposures) in the Bartlesville area elevated?
2. Is the incidence of birth defects in the area elevated? If so, could the increased incidence be caused by the same causes producing birth defects in horses born near the smelter before the smelter used pollution control devices ("smelter colts")?
3. Are behavioral problems of children in the area related to the environmental contamination?
4. Is Multiple Sclerosis (MS) caused by lead and/or cadmium?

The Community Health Concerns Evaluation section of this Public Health Assessment addresses these concerns.

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Contact CDC: 800-232-4636 / TTY: 888-232-6348

PUBLIC HEALTH ASSESSMENT

NATIONAL ZINC COMPANY
BARTLESVILLE, WASHINGTON COUNTY, OKLAHOMA

ENVIRONMENTAL CONTAMINATION AND OTHER HAZARDS

A. On-Site Contamination

Because the proposed National Priorities List (NPL) site incorporates the Zinc Corporation of America facility and all of the known site-related lead and cadmium surface soil contamination in Washington and Osage Counties, there is no "off-site" contamination. Therefore, this Public Health Assessment does not contain a separate section or discussion of "off-site" contamination. This section of the Public Health Assessment is divided into two subsections. The first subsection discusses the environmental contamination found on the Zinc Corporation of America facility. The second subsection is concerned with any environmental contamination found in the community surrounding the Zinc Corporation of America facility which could have originated from National Zinc Company (NZC).

In order to determine what environmental contaminants may be a concern, the Agency for Toxic Substances and Disease Registry (ATSDR) has evaluated all of the available environmental monitoring data (1971 through 1994). Comparison values were used as a basis for evaluation of the data and to determine which contaminants should be looked at more closely. Comparison values are estimated health-based environmental concentrations below which no known or anticipated adverse effect on the health of persons should occur. The values allow an adequate margin of safety. Appendix 2 contains descriptions of the comparison values used in this Public Health Assessment.

A contaminant is selected for further evaluation if the contaminant concentration in a valid environmental sample exceeds comparison values. The presence of a contaminant on the lists in the tables of this section does not mean that either exposure to the contaminant or adverse health effects has occurred or will occur. Inclusion in the list indicates only that the potential for human exposures to the selected contaminants and the potential for adverse human health effects as a result of any exposures to the selected contaminants will be discussed in more detail in later sections of this Public Health Assessment.

1. Environmental Contamination at the Zinc Corporation of America Facility

Ecology and Environment, Inc., inspected the facility on June 2-4, 1981, for EPA (15). Water and soil samples were collected to assess the extent of contamination at the facility. A surface water and sediment sample was taken from Reservoir A, one of the five wastewater impoundments. A groundwater sample was taken from each of the four monitoring wells at the facility. Soil samples (depths not provided) were collected at three locations. Additional samples (depths not provided) were collected from the residue piles at the facility. No volatile or semi-volatile organic compounds were detected at levels above comparison values in any of the samples.

On November 12-13, 1991, U.S. Environmental Protection Agency (EPA) personnel conducted a compliance evaluation inspection (CEI) at the Zinc Corporation of America facility (12). Eighteen samples were taken at the residue piles. During the CEI, the inspectors observed that the piles were marked on all sides by erosion patterns and surrounded by water which remained from a recent rain.

On February 18, 1992, the owners of the Zinc Corporation of America facility sampled the groundwater under the facility from 36 groundwater monitoring wells (12). These samples were analyzed for total metals (arsenic, antimony, barium, beryllium, cadmium, chromium, cobalt, copper, lead, mercury, mercury, nickel, silver, selenium, thallium, tin, vanadium, and zinc). The results of the analyses were reported in the Resource Conservation and Recovery Act (RCRA) permit application submitted by the owners of the Zinc Corporation of America facility.

As required by the EPA RCRA corrective action order of August 1993, the present owners of the Zinc Corporation of America facility have conducted ambient air monitoring near the residue piles and have investigated whether the groundwater metal contamination found at the facility has migrated off the facility (13,14). The results of the ambient air monitoring indicates that the interim dust suppression method is preventing any significant emissions from the residue piles. The groundwater monitoring investigation indicates that some of the groundwater contamination at the facility has migrated towards the south and northwest (arsenic <0.002-0.012 milligrams of arsenic per liter of water [mg/L], <0.02-0.3 mg/L of lead, <0.01-0.03 mg/L of nickel, and 0.4-12.8 mg/L of zinc). Some of the metal concentrations found just off the facility are above health comparison values (0.00002 mg/L for arsenic, 0.007 mg/L for cadmium, 0.1 mg/L for nickel, and 3.0 mg/L for zinc; there is not a health comparison value for ingesting lead). However, the concentration of metals in groundwater off the Zinc Corporation of America facility are significantly less than that found on the facility.

Table 1 shows which contaminants at the facility were detected at levels above comparison values during the 1981, 1991, 1992, 1994 inspections and investigations (12-16).

No stack monitoring (air emission) data is available for the NZC facility. It has been estimated that the facility discharged approximately 1,500 tons (3 million pounds [lbs]) of particulate matter per year before 1976 (7). A review of the EPA Toxic Chemical Release Inventory (TRI) database indicates Zinc Corporation of America released an average of 3,429 lbs of lead, 1,474 lbs of cadmium, and 23,600 lbs of zinc into the air each year from 1987 to 1991 (17).

NZC also discharged sulfur dioxide to the ambient air (16). In July 1977, a major malfunction occurred at the NZC sulfuric acid recovery plant. This malfunction resulted in

Table 1 - Environmental Contaminants Detected Above Health Comparison Values at the Zinc Corporation of America Facility in 1981, 1991, 1992, 1994 (12-16)

Contaminant	Surface Water (mg/L)*	Range in Groundwater (mg/L)	Comparison Value for Ingestion (mg/L)**	Sediment (mg/kg)*	Range in Soil (mg/kg)	Range in Residue Piles (mg/kg)	Comparison Value for Ingestion (mg/kg)**	Range in Ambient Air ($\mu g/m^3$)	Comparison Value for Inhalation ($\mu g/m^3$)**	Comparison Value Source**
Arsenic	30	<10-20	0.00002	147	30-184	1.1-4,350	0.4	NR	0.0002	CREG
Cadmium	21.2	0.02-3,530	0.007 (EMEG)	749	158-230	14-40,700	1 (EMEG)	<0.005-0.22	0.0006 (CREG)	EMEG & CREG
Lead	1.8	<0.04-2.35	None	3250	829-3,220	924-18,100	None	<0.02-0.58	None	None
Manganese	22.1	0.1-0.87	0.05	NR	NR	13,000-444,000	10	NR	1	RMEG
Nickel	1.4	<0.02-0.06	0.1	70.7	17.4-70.7	96-18,800	5.8	NR	2	RMEG
Zinc	760	0.33-8,100	3.0	90,600	4,400-34,500	8,200-782,000	600	NR	57	RMEG

* - This indicates only one environmental sample was taken.
** - See Appendix 2 for a description of the comparison values and their sources.
mg/L - milligrams of contaminant per liter of water, mg/kg - milligrams of contaminant per kilogram of soil, $\mu g/m^3$ - micrograms of contaminant per cubic meter of air, NR - not reported or analyzed.

significantly more sulfur dioxide being discharged than was regularly discharged. Once released to the ambient air, sulfur dioxide converts to sulfuric acid. Residents near the plant reported to the EPA that vegetation damage and human respiratory damage occurred because of the malfunction. From July 28 through September 26, 1977, EPA monitored the ambient air surrounding NZC. Based upon this investigation, EPA concluded that the July incident occurred because of operator error. Long-term emissions from NZC (not just the one event) may have damaged local plants, and certain metals (i.e., lead, zinc, iron, and copper) were found to increase in the ambient air downwind from the plant.

2. Environmental Contamination found in the Surrounding Community

Environmental sampling of surface soil, drinking water, ambient air, and sediment has been conducted in the community surrounding the current Zinc Corporation of America facility since the late 1970s. Table 2 presents results of the historical sampling efforts by EPA and others (1977-1982) (3-6), while Table 3 presents the results of the most current EPA environmental sampling effort (Phases I, II, and III) (18-20). Also included in Table 3 are the results of the Remedial Investigation conducted by the Potentially Responsible Parties (11).

During the current EPA surface soil sampling effort, cadmium was detected 12.6 percent of the time (167/1324) above the action level (30 milligrams of cadmium per kilogram of soil [mg/kg]), while lead was detected in surface soil samples 12.1 percent of the time (160/1324) above the action level (500 mg/kg). The spatial distribution of these metals is coincident with a point source air emission (i.e., the highest levels detected are nearest the former NZC smelter and the surface soil contamination is downwind of the facility) (18).

In addition to comparing the detected concentrations of metals found in surface soils to health based comparison values, it is also prudent to identify whether the detected levels are within the ranges for background or normal soil levels, especially when only a limited number of the soil levels are above the comparison value. According to the U.S. Geological Survey, the typical soil background levels of arsenic, nickel, and zinc are <0.1 to 97 mg/kg, <5 to 700 mg/kg, and 10 to 2,100 mg/kg, respectively. Arsenic was detected above the maximum background level of 97 mg/kg in only 1.6 percent (23/1421) of the samples analyzed in 1991-1992. Because arsenic has been used in various commercial products (e.g., pesticides) and the spatial distribution of the elevated arsenic results is not coincident with air emissions from the NZC facility; the arsenic found in the Bartlesville residential soils does not appear to be a site related contaminant. (Note: Arsenic is found at the facility in the soil and residue piles). Because nickel was not detected above background levels in residential surface soils, this metal is not considered to be a site related contaminant. Zinc was detected above background levels in 19.6 percent (260/1324) of the samples taken in 1991-1992. In addition, the spatial distribution of zinc is coincident with a point source air emission coming from NZC. Therefore, zinc should be considered a site-related contaminant.

Table 2 - Environmental Contaminants Detected Above Health Comparison Values in the Surrounding Community Near the Zinc Corporation of America Facility, 1977-1982 (3-6)

Contaminant	Range in Surface Soil (mg/kg)	Range in Sediment (mg/kg)	Comparison Value for Ingestion (mg/kg)*	Range in Drinking Water (mg/L)	Comparison Value for Ingestion (mg/L)*	Range in Air (µg/m³)	Comparison Value for Inhalation (µg/m³)*	Comparison Value Source*
Arsenic	37-84	59-64	0.4	<0.010	0.00002	NR	0.0002	CREG
Cadmium	<1-500	115-278	1 (EMEG)	<0.002	0.007 (EMEG)	<0.03-0.26	0.0006 (CREG)	EMEG & CREG
Lead	8-3,008	1,100-1390	None	0.004-0.007	None	0.17-2.5	None	None
Manganese	NR	NR	10	<0.02	0.05	NR	1	RMEG
Nickel	18-32	78-86	5.8	NR	0.1	NR	2	RMEG
Zinc	260-38,300	18,100-21,100	600	0.007-0.055	3.0	NR	57	RMEG

* - See Appendix 2 for a description of the comparison values and their sources.
mg/kg - milligrams of contaminant per kilogram of soil
mg/L - milligrams of contaminant per liter of water
µg/m³ - micrograms of contaminant per cubic meter of air
NR - not reported or analyzed

Table 3 - Environmental Contaminants Detected Above Health Comparison Values in the Surrounding Community Near the Zinc Corporation of America Facility, 1991-1994 (11,18-20)

Contaminant	Range in Surface Soil (mg/kg)	Range in Sediment (mg/kg)	Comparison Value for Ingestion (mg/kg)*	Range in Surface Water (mg/L)	Range in Drinking Water (mg/L)	Comparison Value for Ingestion (mg/L)*	Range in Air (µg/m³)	Comparison Value for Inhalation (µg/m³)*	Comparison Value Source*
Arsenic	0.5-1,000	11-165	0.4	0.001-0.0028	<0.015	0.00002	<0.05	0.0002	CREG
Cadmium	0.2-1,372	16-462	1 (EMEG)	<0.001-0.398	<0.002	0.007 (EMEG)	<0.002-0.61	0.0006 (CREG)	EMEG & CREG
Lead	0.84-11,908	19-2,566	None	0.001-0.013	<0.005-0.035	None	0.05-6.8	None	None
Manganese	NR	NR	10	NR	NR	0.05	NR	1	RMEG
Nickel	NR	NR	5.8	NR	NR	0.1	NR	2	RMEG
Zinc	13.7-109,000	27-18,300	600	0.022-15.6	NR	3.0	0.01-18	57	RMEG

* - See Appendix 2 for a description of the comparison values and their sources.
mg/kg - milligrams of contaminant per kilogram of soil
mg/L - milligrams of contaminant per liter of water
µg/m³ - micrograms of contaminant per cubic meter of air
NR - not reported or analyzed

During the Remedial Investigation, 4 surface soil samples were taken from gardens located in the area of Bartlesville with the highest surface soil contamination (south of West Hensley Boulevard and west of Short Avenue) (11). Analytical results of these samples found 3.7 to 12.9 mg/kg of arsenic, 3.2 to 66.6 mg/kg of cadmium, 65.4 to 339 mg/kg of lead, and 564 to 6,680 mg/kg of zinc. Surface soil samples were also taken from 12 gardens in Oak Park Village. Analytical results of these samples found 2.6 to 9.3 mg/kg of arsenic, 0.7 to 11.4 mg/kg of cadmium, 11.2 to 194 mg/kg of lead, and

86.9 to 1,020 mg/kg of zinc.

Surface water and sediment samples were taken from drainage ditches, the North Tributary, and the West Tributary through which storm water from the Zinc Corporation of America facility flows (11,18). In addition, surface water and sediment samples were taken from the Eliza Creek, the Sand Creek, and the Caney River. Analytical results of the samples indicate that arsenic, cadmium, lead, and zinc are present in the ditches, tributaries, and creeks above background levels. Most of the high concentrations of these contaminants were found in the drainage ditches, the North Tributary, and the West Tributary near the facility. The highest concentrations were found in the North Tributary. Analytical results of samples taken from the Sand Creek and the Caney River indicate that arsenic, cadmium, lead, and zinc are at background levels within these bodies of water.

EPA has conducted two ambient air monitoring studies in the community surrounding NZC. The first study was conducted shortly after the major malfunction at NZC in 1977 (16). The analytical results of samples taken indicated that the air contained cadmium at concentrations of less than 0.03 micrograms of cadmium per cubic meter of air ($\mu g/m^3$) (the analytical detection limit) to 0.26 $\mu g/m^3$ downwind of NZC. Lead was detected at 0.17 $\mu g/m^3$ to 2.5 $\mu g/m^3$ during the 1977 study.

The second EPA ambient air monitoring study was conducted in 1992. This study found cadmium and lead concentrations of less than 0.002 to 0.61 $\mu g/m^3$ and 0.05 to 6.8 $\mu g/m^3$ respectively (16). However, the highest level of cadmium detected (0.61 $\mu g/m^3$) was invalidated because the location where this sample was taken was more representative of street dust than ambient air concentrations.

The City of Bartlesville Water Department has taken 135 drinking water tap samples (1992-1993). All of these samples were taken without flushing the standing water from the household pipes (first draw). The Oklahoma State Environmental Laboratory analyzed all of the samples for lead. According to the laboratory analysis, only 2 of the 135 tap samples (1.5 percent) contained lead above the laboratory detection limit of 0.005 mg/L (0.035 and 0.007 mg/L). Both of these drinking water taps had been sampled previously. Analytical results for the previous sampling period did not find lead above the laboratory detection limit of 0.005 mg/L (20). The two samples containing lead above detection levels probably represent lead pipe solder within those homes and not site-related contamination.

The City of Bartlesville Water Department also takes drinking water samples to determine whether the city drinking water contains any chemicals above the EPA Safe Drinking Water Act Maximum Contaminant Levels. Analysis of these samples was conducted by the Oklahoma State Environmental Laboratory. The analytical results indicate that there are no chemicals in the City of Bartlesville drinking water above health comparison values (20).

B. Quality Assurance and Quality Control

ATSDR was able to obtain quality assurance and quality control (QA/QC) information for most of the data presented in this Public Health Assessment. This information indicates appropriate QA/QC was performed for the samples. The conclusions presented in this Public Health Assessment are based in part on the data presented. The validity of the conclusions, therefore, depends on the accuracy and reliability of the data provided.

C. Physical and Other Hazards

No physical or other hazards, except those normally found at an industrial facility or residential area, were noted during the ATSDR site visit.

D. Review of Toxic Chemical Release Inventory (TRI) Data

To identify possible facilities that could contribute to the surface soil contamination in Bartlesville, ATSDR searched the 1987 to 1991 files of the Toxic Chemical Release Inventory (TRI) databases for the zip codes where the site is located (74003, 74004, 74005, and 74006) (17). TRI was developed by the EPA from chemical release information (air, water, and soil) provided by certain industries.

Several limitations of TRI data should be noted (21). The air release data in TRI may be estimates or actual measurements. Many of the reported data are estimates based on conservative (overestimated) scenarios. Consequently, the levels of emissions recorded in TRI are often biased on the high side. In addition, reporting is restricted to specific chemicals that are used or released above specified amounts. Finally, it is believed there have been and still are industries that do not report releases. Smaller industries may not be aware that reporting requirements exist or that they are responsible for such reports.

The search of TRI indicates that four facilities within the selected zip codes have discharged chemicals to the environment (17). Only Zinc Corporation of America and B&W Micronutrients reported discharging any of the chemicals identified in this Public Health Assessment. As previously discussed, Zinc Corporation of America released to the air an average of 3,429 lbs of lead, 1,474 lbs of cadmium, and 23,600 lbs of zinc each year for the years 1987 to 1991. B&W Micronutrients reported releases to the air of an average of 2,025 lbs of zinc each year for the years 1988 to 1991. These air releases should not contribute significantly to the surface soil contamination in Bartlesville.

PATHWAY ANALYSES

In this section of the Public Health Assessment, the possible environmental exposure pathways are evaluated to help determine whether individuals have been, are being, or will be exposed to site-related contaminants. The pathway analysis consists of five elements:

1. identifying contaminants of concern possibly related to the site;

2. determining that contaminants have been, are being, or will be transported through an environmental medium;
3. identifying a point of exposure (i.e., a place or situation where humans might be exposed to the contaminated media);
4. determining that there is a plausible route of human exposure (i.e., can the contaminant enter the body?); and
5. identifying an exposed population (i.e., how many people, if any are at the point of exposure?).

An environmental exposure pathway is considered complete when there is good evidence that all five elements exist (22). The presence of a completed pathway indicates that human exposure to contaminants has occurred in the past, is occurring, or will occur in the future. When one or more of the five elements of an exposure pathway are missing, that pathway is considered potential. The presence of a potential exposure pathway indicates that human exposure to contaminants could have occurred in the past, could be occurring, or could occur in the future. An exposure pathway can be eliminated from consideration if at least one of the five elements is missing and will never be present. If there is uncertainty about the site-relatedness of the contaminants of concern in an exposure pathway, the pathway will be evaluated as if the contaminants were site-related.

The completed environmental exposure pathways, the potential environmental exposure pathways, and the specific pathways eliminated from consideration are discussed below. In addition, Appendix 3, Tables 1 and 2, present the estimates of the number of exposed individuals at the proposed NZC NPL site. The population estimates are based upon the information contained in the EPA Hazard Ranking System Report for the proposed NZC NPL site (the number of residences within an one mile-radius from the facility) (23).

A. Completed Environmental Exposure Pathways

There is good evidence that people have been, are being, and will continue to be exposed to surface soil contamination through ingestion, inhalation, and skin contact at the proposed National Zinc Company (NZC) National Priorities List (NPL) site (the "Surface Soil" pathway). In addition, people have been exposed to direct ambient air discharges from past operations at the NZC facility through inhalation, ingestion, and skin contact (the "Air" pathway).

1. Surface Soil

Analysis of surface soil samples (0-3 inches) clearly demonstrates cadmium, lead, and zinc contamination at levels above health comparison values. The contaminated surface soil is found at the Zinc Corporation of America facility and in the surrounding residential areas. Individuals, primarily children, will be exposed to the surface soil contamination via inadvertent consumption and skin contact with the soil on hands or food items, mouthing of objects, or the ingestion of nonfood items (pica). In addition, these individuals will inhale the soil contaminants whenever the surface soil is disturbed (e.g., dust and particulate matter). All children mouth or ingest nonfood items to some extent. The degree of pica behavior varies widely in the population, and is influenced by nutritional status and the quality of care and supervision. Groups that are at increased risk for pica behavior are children aged 1 to 3 years old, children from families of low socioeconomic status, and children with neurologic disorders (e.g., brain damage, epilepsy, and mental retardation).

Analysis of surface soil and residue pile samples at the smelter facility revealed cadmium, lead, and zinc contamination at higher levels than those found in the residential soils. Therefore the workers at the smelter can ingest, inhale, and have skin contact with the surface soil and residue pile contamination.

The blood lead studies funded by the Agency for Toxic Substances and Disease Registry (ATSDR) and performed by the Oklahoma State Department of Health (OSDH and the Oklahoma Department of Environmental Quality (ODEQ) in 1991 and 1992 clearly indicate that blood lead levels in children are higher in the area where surface soils are contaminated with high levels of lead (see discussion in the Health Outcome Data Evaluation section). These studies strengthen the determination that people have been, are being, and can be exposed to surface soil contamination.

2. Air

No stack monitoring data are available for the operational activities that occurred at NZC in the past. However, it has been estimated that the facility smelter discharged approximately 1,500 tons (three million pounds [lbs]) of particulate matter per year into the ambient air prior to 1976. The chemical makeup of the particulate matter would have included the metals detected in the residue piles and in the residential soils (primarily cadmium, lead, and zinc). The 1977 and 1992 ambient air monitoring indicated that cadmium and lead were being discharged into the ambient air from the smelter. In addition, the magnitude of the air discharges is reflected by the very high levels of surface soil contamination found at the facility and in the residential soils; the primary cause of the residential soil contamination is air deposition of air discharges from the smelters. Therefore, individuals working at the smelters and/or living near the NZC facility would have inhaled, ingested, and experienced skin contact with the particulate matter being discharged by NZC.

The 1975 and 1977 epidemiologic studies conducted in Bartlesville confirm that individuals were exposed to high levels of lead and cadmium (see discussion in the Health Outcome Data Evaluation section). These studies found that children in the Bartlesville area had higher blood lead and cadmium concentrations than the concentrations of children who did not live near a zinc smelter.

Since NZC changed the metal extraction process, the direct discharges to the ambient air have been greatly reduced. In addition, the facility attempts to mitigate the dispersion of metals from the residue piles by spraying the piles with a latex material.

Besides the particulate and metal discharges, NZC also discharged sulfur dioxide to the ambient air. The major malfunction that occurred at the NZC sulfuric acid recovery plant in July 1977 resulted in significantly more sulfur dioxide being discharged than is regularly discharged. Once released to the ambient air, sulfur dioxide converts to sulfuric acid. Residents near the plant reported to the U.S. Environmental Protection Agency (EPA) that vegetation damage and human respiratory damage occurred because of that malfunction. Based upon the July 28 through September 26, 1977, investigation, EPA concluded that the July incident occurred because of operator error; long term emissions from NZC may have damaged local plants; and certain metals (i.e., lead, zinc, iron, and copper) were found to increase in the ambient air downwind from the plant. Therefore, it is likely individuals were exposed (i.e., via inhalation, ingestion, and skin contact) to elevated levels of sulfuric acid in the ambient air.

B. Potential Environmental Exposure Pathways

People could potentially be exposed to site-related contaminants via sediment, surface water and biota. These potential pathways could have occurred in the past, could be occurring now, or could occur in the future. In addition, the ambient air could become contaminated whenever the residue piles at the Zinc Corporation of America facility or the contaminated subsurface soils (greater than 3 inches) are disturbed.

1. Sediment and Surface Water

Surface water runoff (storm water) and wastewater generated at the Zinc Corporation of America facility are retained and treated (sedimentation) in the facility impoundments and disposed of via two permitted injection wells. Under normal operational conditions no surface water or sediment from the facility should move off-site. However, the owners of the facility have reported off-site releases of storm water runoff because of overtopping of the impoundments during storms. Nine releases have been reported to the Oklahoma Water Resources Board (eight from 1985 to 1987 and one on May 4, 1991).

Analysis of surface water and sediment samples from one of the facility wastewater impoundments and one of the ditches on the facility indicates that arsenic, cadmium, lead, manganese, nickel, and zinc could migrate beyond the facility boundaries. Analysis of sediment samples taken in the ditches, the North Tributary, and the West Tributary near the facility indicates that cadmium, lead, and zinc have migrated beyond the facility boundaries. Individuals could potentially be exposed to the sediment contamination via inadvertent consumption, inhalation, and skin contact with the sediment. Ingestion, inhalation, and skin contact with the surface water contaminants could potentially occur during heavy storm. However, such exposures are not likely to occur very frequently.

It is unlikely that the general public would be exposed to the contaminated sediment and surface water at the facility, because access to the facility is restricted. The total facility is surrounded by an 8-foot fence and is patrolled 24 hours a day. Workers could potentially ingest, inhale, or have skin contact with the sediment and surface water at the smelter.

2. Biota

Any plants grown in the soils contaminated with cadmium, lead, and zinc will have the tendency to incorporate the metals in the plant tissue (uptake) (24-26). In general, metals may accumulate on plant surfaces as a result of atmospheric deposition of dust or particles containing the metals. The metals may enter plant tissues through absorption of particles that adhere to foliage surfaces and/or via active transport through the roots. The higher metal concentrations in plants are found in the older parts of the plants.

During the October 1993 site visit, ATSDR staff members saw residential-area garden plots that could have high surface soil concentrations of cadmium, lead, and zinc. Analytical results of surface soil samples taken from garden plots within the affect areas of Bartlesville indicate that these gardens contain metal concentrations which are slightly elevated above back ground levels (11). These sampling results may be representative of present conditions. However, the metal concentrations in the past may have been higher until the tilling of the soil and importation of soil amendments each season reduced the metal concentration in the garden plots. Any plants grown in these plots before the metal concentrations were reduced may have accumulated higher cadmium, lead, and zinc concentrations than plants grown outside the contaminated area would accumulate. Therefore, individuals ingesting or experiencing skin contact with these plants may have been exposed to the metals accumulated in the plants.

Fish can bioaccumulate cadmium, lead, and zinc (24-26). However, analysis of surface water and sediment samples from Sand Creek and the Caney River indicate there is not any significant metal contamination in these bodies of water (11). Some elevated levels of cadmium, lead and zinc were found in the Eliza Creek near the location where the North Tributary connects to the Eliza Creek. Sand Creek and Caney River are used for recreational fishing. Some recreational fishing may take place in the Eliza Creek, but not as frequently. Therefore, it is not likely anyone would be exposed to any significant amount of metals from fish in the Eliza Creek, Sand Creek, or the Caney River.

3. Residue Piles and Subsurface Soils

Because there are very high concentrations of metals in the residue piles (i.e., arsenic, cadmium, lead, manganese, nickel, and zinc) and in the residential subsurface soils (i.e, cadmium, lead, and zinc), these metals could be released to the ambient air as dust and particulate matter whenever the piles or soils are disturbed. During the October 19-20, 1992, site inspection, EPA personnel observed particles being blown from some of the residue piles. Therefore, individuals (e.g., workers) near the residue piles or residential soils whenever they are distributed could potentially inhale, ingest, and have skin contact with the dust and particulate matter and be exposed to the metals.

The 1993 Resource Conservation and Recovery Act (RCRA) corrective action order requires the owners of Zinc Corporation of America to design and implement procedures to prevent particles from being blown from the residue piles (12). The owners of Zinc Corporation of America have implemented an interim dust suppression program. Analytical results of ambient air samples taken near the residue piles indicate that the interim dust suppression program has significantly reduced the emission of dust and particulate matter from the piles. Therefore, it is unlikely anyone should be exposed to a significant amount of dust or particulate matter from the residue piles; provided the dust suppression program continues to be implemented.

C. Specific Pathways Eliminated From Consideration

Two exposure pathways have been eliminated from consideration. These are human exposures to site-related contaminants in drinking water and groundwater.

1. Drinking Water

Analysis of samples from the Bartlesville drinking water supply system (past and present) did not detect any significant amounts of site related contaminants. Therefore, it is not likely that humans were exposed to site-related contaminants by ingesting drinking water. The drinking water source for the City of Bartlesville is north of the proposed NPL site and is not likely to become contaminated as a result of the proposed NZC NPL site.

2. Groundwater

Analysis of samples taken from monitoring wells at and near the Zinc Corporation of America facility indicates that the groundwater directly under the facility is highly contaminated with arsenic, cadmium, lead, and manganese (i.e., above health comparison values) (12,13,14). The contamination has moved toward the northwest and south. However, this contamination does not appear to have migrated very far off the facility's property. According to EPA, no drinking water wells exist within a 3-mile radius of the facility. Therefore, it is unlikely that any drinking water wells have been contaminated with facility-related metals.

D. Other Sources of Lead Exposures

Lead is a naturally occurring element that has been used almost since the beginning of civilization. Because of the many industrial activities that have brought about its wide distribution, lead is ubiquitous in the environment today. All humans have lead in their bodies, primarily as a result of exposure to manufactured sources (25).

In addition to the emissions from the NZC plant, other environmental sources of metallic lead and its salts are paint, auto exhaust, and food. For Bartlesville children, the most important pathways other than the smelter are ingestion of chips from lead-painted surfaces, inhalation of lead from automobile emissions (past exposure because lead is no longer used in gasoline), and food from lead-soldered cans (past exposure because lead-solder is no longer used in food cans) (25).

The lead content of paint was not regulated until 1977. Many older structures, residential and commercial, have leaded paint that is peeling, flaking, and chipping. Children can ingest loose paint as a result of pica behavior and through mouthing of items contaminated with lead from paint, dust, and soil. High levels of lead in soil and house dust have been associated with increased blood lead levels in children (25). It has been estimated (based upon house paint samples) that 29 percent of the homes in Bartlesville have interior lead paint (27).

In addition to the environmental sources, many occupations, hobbies, and other activities result in potential exposures to high levels of lead and can put the entire family at risk of lead poisoning (25). Plumbers, pipe fitters, printers, smelter workers, and battery manufacturing workers can be exposed to lead at the work place. These workers can also bring the lead into their homes via dirty clothing. Hobbies and other activities which have the potential for high lead exposures include making glazed pottery, lead soldering (e.g., in electronics manufacturing or repair), making stained glass, and target-shooting at firing ranges. Lead-glazed pottery, particularly if it is imported, is a potential source of exposure that is often overlooked.

PUBLIC HEALTH IMPLICATIONS

As discussed in the Pathways Analyses section, the surface soil and the ambient air exposure pathways are considered completed (i.e., human exposure has occurred or is occurring). The contaminants of concern are cadmium, lead, and zinc for the surface soil and ambient air pathways; in addition, sulfuric acid is a contaminant of concern for the ambient air pathway.

The Toxicological Evaluation portion of this section discusses the possible health hazard from exposure to the contaminants of concern in surface soil and ambient air. Community health concerns are addressed in the Community Health Concerns Evaluation section, and health outcome data are discussed in the Health Outcome Data Evaluation section.

A. Toxicological Evaluation

1. Introduction

Typically, the toxicological evaluation in a public health assessment is a comparison of the estimated exposure dose (i.e., the amount of a substance individuals in an exposure pathway are exposed to daily) with an appropriate health guideline. The guideline is usually either the Agency for Toxic Substances and Disease Registry's (ATSDR's) Minimal Risk Level (MRL) or the Environmental Protection Agency's (EPA's) Reference Dose (RfD). The MRLs and RfDs are estimates of daily human exposure to a contaminant below which noncarcinogenic adverse health effects are unlikely to occur (22). That means that any exposure dose below the appropriate MRL or RfD does not represent a hazard to human health. However, for exposure doses above an MRL or RfD, there is a significant degree of uncertainty about whether adverse health effects will occur. Therefore, a review of the toxicological literature is done to determine whether the specific exposure situation represents a hazard to public health. The results of the comparison of exposure doses to health guidelines, and the methodology for calculating the exposure doses are described in Appendix 4.

In addition to evaluating those exposures where ATSDR was able to determine the level of exposure (i.e., calculating an exposure dose), the possible health consequences of the 1977 sulfuric acid incident is discussed.

There are no health guidelines for exposure to lead in soil, so the exposure doses for lead in this medium can not be evaluated directly. However, blood lead concentrations do relate well to possible health effects (25). The blood lead studies conducted in the Bartlesville area are discussed in the Health Outcome Data Evaluation section.

The adult, children, and pica children exposure doses for the maximum cadmium level in the surface soil exposure pathway exceed the cadmium health guideline. The children and pica children exposure doses also exceed the health guidelines for the maximum zinc level in the surface soil exposure pathway, but the adult exposure doses do not. The possible health consequences of exposure to those chemicals which exceed the health guidelines are discussed.

For the ambient air exposure pathway, the air contaminant concentrations were compared directly to inhalation MRLs without any additional calculation. Cadmium in the ambient air of the surrounding community exceeded the inhalation health guideline. This result is discussed.

One of the three contaminants of concern, lead, is considered a probable human carcinogen when contacted through ingestion and inhalation routes, and another, cadmium, is considered carcinogenic only when contacted through the inhalation route (28). In the only relevant study, zinc has not been shown to cause cancer in one laboratory animal (26). EPA has not made a determination as to whether zinc could potentially cause cancer in humans (28). There is currently no scientific data on how strong lead is as a cancer causing chemical (i.e., cancer potency factor) (28). Therefore, only the risk of cancer because of exposure to cadmium could be evaluated.

2. The Possibility of Health Consequences

The possible health consequences of those exposure doses that exceeded health guidelines--cadmium and zinc--are described in the following paragraphs. Exposure to sulfuric acid is also discussed.

Health assessors determine the possibility of health consequences by comparing the exposure to the results of epidemiologic evaluations of human exposures to a chemical. If valid human data are not available, information from properly conducted animal studies are used. The type of data used for an evaluation is indicated for each chemical.

a. Cadmium

Soil

Based on human data, there is some possibility of noncarcinogenic health effects for children exposed to cadmium in residential soil (24). Soil concentrations of cadmium of 375 mg/kg and greater result in exposure doses for small children (10 kilograms [Kg]/22 pounds [lbs]) that exceed the lowest observed effect level in humans of 0.0075 milligrams of cadmium per kilogram body weight per day (mg/kg/day). For small children who ingest large amounts of soil (i.e., pica children), the lowest effects level is exceeded when the cadmium level exceeds 15 milligrams of cadmium per kilograms of soil (mg/Kg). Cadmium soil levels in the community around the Zinc Corporation facility vary from 0.2 through 1,372 mg/kg.

The lowest observed effect for ingestion of cadmium in humans is proteinuria, which is the discharge of proteins from the kidney into the urine (24). Epidemiologic studies of individuals living a lifetime in cadmium-contaminated areas in Japan, Belgium, and China identified rates of proteinuria that were statistically greater than rates identified in uncontaminated areas. Proteinuria is considered a mild adverse effect on the kidney. Human studies do not identify a dose where more serious kidney problems begin. Animal studies indicate this level may be about 5 times greater than the exposure dose for small children with the habit of pica and 130 times greater than for small children who do not ingest large amounts of dirt.

Other animal studies reveal that serious developmental and immunological effects begin to be observed at 3 and 70 times greater than the exposure doses for pica children and small children respectively (24). Because of animals' and humans' differences in responses to toxins, it is possible that these more serious effects could occur.

Air

Based on a study of workers exposed to cadmium for 30 years (not related to the National Zinc Company [NZC] or the Zinc Corporation of America facility), it is possible to conclude that air cadmium levels of 0.2 micrograms of cadmium per cubic meter of air ($\mu g/m^3$) or greater could cause mild damage to the kidney as evidenced by an increase in proteinuria (24). There is no ambient air monitoring data during the historically high air emissions from the smelter. It has been estimated that the facility discharged approximately 1,500 tons of particulate matter per year before 1976. Given the high cadmium surface-soil contamination and the high levels of cadmium measured in the blood and hair of people living near the smelter, it is possible that the ambient air concentrations of cadmium near the smelter could have exceeded 0.2 $\mu g/m^3$ for a significant period of time.

Nine percent of the workers, in the aforementioned study, exposed to 23 $\mu g/m^3$ of cadmium for 30 years had proteinuria, while the usual rate of proteinuria in an unexposed population is 5% (24). Because those exposed were healthy workers, it is reasonable to conclude that more sensitive individuals, such as children or the elderly, could experience health effects. When there are no data for those sensitive individuals, the effects level for the workers is adjusted downward by a factor of 10. Measured air levels at Bartlesville of 0.2 $\mu g/m^3$ or greater lie within the zone of concern for sensitive individuals.

As described in the Environmental Contamination and Other Hazards section, the measurement of air cadmium levels was done after significant emission controls had been installed at the smelter in 1977. Therefore, it is probable that exposure levels were higher prior to 1977, and that the chance of adverse health effects due to cadmium was also higher, especially given the maximum exposure length of 70 years.

Combined Exposures

It is likely that residents of the area around the smelter are exposed to cadmium both through ingestion and inhalation and that those residents' risk of health effects would therefore be greater. Because there are differences in the way the body metabolizes inhaled versus ingested cadmium, it is not possible to calculate what this greater risk might be.

Risk of Cancer

Evidence (i.e., the high surface concentrations of cadmium, the high particulate emission rate, and the high blood and hair cadmium levels in people) indicates that people living near the smelter could have been exposed to high levels of cadmium in the ambient air. This exposure could represent a moderate increase in the risk of cancer for residents around the smelter. The cancer slope factor on which this conclusion is based comes from a study of cadmium smelter workers (not related to NZC) exposed for 6 months to 29 years to dust and fumes from cadmium and other metals (28). The study identified a two-fold increase in the rate of lung cancer. Other causes of lung cancer, such as smoking or arsenic, were properly taken into account.

b. Zinc

Based on human data, there is some possibility of noncarcinogenic health effects for children exposed to zinc in residential soil (28). Soil concentrations of zinc of 50,000 mg/kg and greater result in exposure doses for small children (10 Kg/22 lbs) that exceed the lowest observed effect level in humans of 1.0 mg/kg/day. For small children who ingest large amounts of soil (i.e., pica children), the lowest effects level is exceeded when the zinc level exceeds 2,000 mg/kg. Zinc soil levels in the community around the Zinc Corporation facility vary from 13.7 through 109,000 mg/kg.

The lowest observed effect for ingestion of zinc in humans is a 47% decrease in the level of the enzyme erythrocyte superoxide dismutase, which regulates the copper levels in the body (28). A long-term decrease in erythrocyte superoxide dismutase would result in a copper deficiency. Small children likely experience this effect at a higher dose than adults because children metabolize zinc more slowly than adults. Therefore, children would need more zinc per unit body weight than adults for this effect to occur. Zinc is an essential nutrient, and the recommended daily allowance for children, 10 milligrams of zinc per day (mg/day), is actually the same dose, 1 mg/kg/day, for a 10 Kg child as the lowest observed effect level seen in studies of adults (29). Studies of adults indicate that it is unlikely that small children who do not have the habit of pica (ingesting 5 or more grams of soil a day) would experience other health effects (28). Pica children ingesting soil contaminated with levels of zinc greater than 4,000 mg/kg could possibly experience a decline in high-density lipoprotein levels, or impairment of immune response. Because of the zinc metabolism differences between adults and children, it is uncertain that these health effects would occur in children.

c. Interactions Between Cadmium, Lead, and Zinc

Zinc is an essential element from the diet (26). However, there are no known benefits of cadmium or lead (24,25). Many different metals (e.g., calcium) and nutrients interact with the absorption, distribution, and excretion of cadmium, lead, and zinc. There is some evidence that these interactions may reduce the amount of cadmium, lead, and zinc absorbed into the body. In addition, cadmium, lead, and zinc compete for some similar target sites inside the body. This competition may result in decreased accumulation of cadmium in cells. If this occurs, the toxic effects of exposure to cadmium would be reduced. There are some studies which indicate that simultaneous exposure to cadmium and zinc decreases the toxic effect of cadmium. In addition, zinc may have a protective effect against lead toxicity. However, some toxicological studies indicate that simultaneous exposure to lead and cadmium increases the toxic effects. As indicated by this discussion, there are many factors which influence these interactions (e.g., the dose of each metal, the nutritional status of the person exposed, etc.) and at this time it is not possible to precisely predict how cadmium, lead, and zinc may interact when people are exposed simultaneously to all three metals.

d. Sulfuric Acid

As described in the Pathways Analyses section, there was a major malfunction of the NZC sulfuric acid recovery plant in July 1977, resulting in the release of excessive amounts of sulfur dioxide (16). Residents around the NZC facility reported that the release caused health effects. Those effects and the chance of long-term consequences from the exposures are discussed.

Once in the air, sulfur dioxide can be converted to sulfuric acid, especially in the presence of certain metals (30). This is important because sulfuric acid is much more toxic (i.e., causes harm at much lower concentrations) than sulfur dioxide. The two chemicals are identical in the health effects caused, which are the irritation and eventual burning of the eyes, nose, throat, lungs, and skin at the time of exposure. In addition, the teeth can be etched. While those effects can be permanent, they are not delayed in their onset. Thus, any health consequences of the exposure in July 1977 would have occurred at that time, and not later.

B. Health Outcome Data Evaluation

In this section, health outcome data of two types are reviewed and evaluated: cancer mortality data for Washington County, and lead and cadmium data for Bartlesville residents. In addition, the guidelines that ATSDR follows for evaluating information from health outcome databases are reviewed.

1. Introduction

In a public health assessment, available health outcome databases are identified for the area near the site. From those data, ATSDR selects health outcomes for further evaluation based on biological plausibility or community health concerns (22).

For biological plausibility, the decision to evaluate health outcome data depends on whether a completed exposure pathway exists for a chemical suspected of causing the health outcome of concern (22). The selection of a noncarcinogenic health outcome is based on a review of the toxicologic literature for that contaminant of concern.

When a contaminant of concern has been identified as a carcinogen, health outcomes for the major anatomical sites are usually selected for evaluation (22). Designating a chemical as a carcinogen for purposes of health outcome data evaluation is based on the following criteria:

a. Classification by the National Toxicology Program (NTP)[(1)] in its Annual Report on Carcinogens as a "known human carcinogen" or "reasonably anticipated to be a carcinogen"; or
b. Classification by the International Agency for Research on Cancer (IARC)[(2)] as a 1, 2A, or 2B carcinogen; or
c. Classification by EPA[(3)] as an A, B1, or B2 carcinogen.
d. Classification by the United States Occupational Safety and Health Agency (OSHA)[(4)]

A latency period of at least 10 years between exposure and diagnosis has been observed in most studies of human cancer (22). If exposure began less than 10 years prior to the latest data available, analysis of health outcome data for cancer incidence or mortality is not likely to be useful, particularly if the exposure level is low.

Even when health outcomes do not meet ATSDR's guidelines for biological plausibility, evaluation of health outcome data can provide a basis for addressing community health concerns.

Cancer is considered a biologically plausible health outcome because cadmium and lead are considered probable human carcinogens and because both contaminants are in completed air and soil human exposure pathways (24,25). Significant exposure to lead and cadmium in air and soil occurred for about 70 years.

Developmental or birth defects were considered biologically plausible health outcomes. Lead is strongly associated to those effects and is in the air and soil completed exposure pathways (25).

Neither cancer incidence nor birth defects data could be evaluated in this public health assessment because The Oklahoma State Tumor and Birth Defect Registries have no accessible data for Washington County for either cancer or birth defects. Cancer incidence data have been collected for Washington County by the local hospital for several years; however, those data are currently not compatible with the state's system. The Oklahoma State Department of Health (OSDH) is in the process of making the Washington County data compatible. The Oklahoma Birth Defects Registry is scheduled to incorporate Washington County data into the state system in 1994/1995.

2. Cancer Mortality Data

To identify cancer mortality rates, ATSDR reviewed mortality data on 30 anatomical sites for Washington County. The database used for the review is maintained by the Office of Analysis and Epidemiology of the National Center for Health Statistics, Centers for Disease Control and Prevention (CDC).

Information specific to the City of Bartlesville area is not available. Mortality data for Washington County were accessed for 1979 to 1988, the only years available. The age-adjusted rates for Washington County were compared to the rate for Oklahoma. Because the Bartlesville area is about 91% white, the comparisons listed below will be for whites. The comparison of rates for African-Americans and others produced results similar to those described in the following paragraphs.

Of the 30 anatomical sites evaluated, the number of deaths for multiple myeloma and ovarian cancer in Washington County was greater than what would be expected from the numbers for the State of Oklahoma. There were 25 deaths from multiple myeloma in Washington County for 1979 to 1988, while 15 would have been predicted based on the 1,031 deaths for the State of Oklahoma. There were 34 deaths from ovarian cancer, while 22 would have been expected based on the 1,498 deaths for the state.

The available data on cadmium and lead do not identify ovarian cancer or multiple myeloma as possible health outcomes (24,25). Human studies do not identify any cancers associated with exposure to lead. Occupational studies indicate that cadmium may be a weak lung carcinogen. Animal studies indicate that cadmium can cause lung cancer and that lead can cause kidney cancer. For Washington County, the occurrence of lung and kidney cancer was as expected from the state rates.

a. Ovarian Cancer

The rates of ovarian cancer are greatest in highly industrialized countries and in women 40 to 70 years old (38). There is an indication of some kind of environmental or dietary influence on the occurrence of this cancer, based on studies of Japanese women. The rate of ovarian cancer in Japan is one of the lowest in the world. However, the rate in Japanese who move to the United States as children is close to that for white Americans. However, the only proven association with an environmental agent is the association with asbestos. No association was demonstrated for viruses, radiation, or other substances. There is also an association of ovarian cancer with disordered endocrine function. Occurrence is greater in women who had few or no pregnancies or were infertile.

b. Multiple Myeloma

Multiple myeloma is a cancer in which there is an over production of defective B-cells (39). B-cells are a type of white blood cells. Multiple myeloma makes up about 1% of all cancers in whites and 2% in African-Americans. The average age of onset is about 70 years. Factors such as family history of multiple myeloma and exposure to petroleum products, asbestos, and radiation have been associated with the occurrence of multiple myeloma. This cancer has not been associated with cadmium and lead.

c. Limitations

Evaluations of cancer mortality data have limitations. The cancer mortality data used do not include information on personal risk factors (smoking, diet, alcohol, etc.) or on occupational and environmental exposures to chemicals. Analyses of those data can only be descriptive and cannot be used to determine associations with possible agents. There is an inherent 5% chance that any excess in observed cancer cases is due to random variation alone.

Another limitation is whether mortality data reflect the actual frequency of a health outcome (i.e., deaths plus those who survive) (40). Factors such as quality of health care, high survival rates, and misclassification of cause of death can lead to differences in mortality rates even though the true frequency of the health outcome has not changed.

3. Studies of Contaminants in Body Tissues

Testing blood, tissue, or other body fluids from individuals living around a site for possible site contaminants can identify whether exposure has occurred and whether contaminant concentrations are high enough to cause adverse health effects. The linking of elevated levels of a contaminant to a site requires the evaluation of other possible exposure sources.

The body tissue data for Bartlesville residents indicates that exposure to site-related cadmium and lead has occurred in the past. Only blood lead studies have been conducted recently (1991 through 1993). These studies indicate that people are presently being exposed to lead. This conclusion is based on the identification of elevated blood lead and cadmium concentrations, elimination of other possible exposures, and an association between soil cadmium and lead levels and blood cadmium and lead levels.

a. Review of Blood Contaminant Data

There are four major sets of data on blood cadmium and lead for the Bartlesville area during the 1970s (2,3,9). In 1975, CDC conducted a study of 19 cities with lead, copper, or zinc smelters and found that 78 of 87 Bartlesville children (89.6%) had blood lead levels above 10 micrograms of lead per deciliter of blood (µg/dL), 33 of 87 (37.9%) had levels above 30 µg/dL, and 3 of 87 (3.4%) had levels above 80 µg/dL (2). Those children were 1 to 5 years old, and each lived within 4 miles of the NZC smelter. The mean blood lead level for the 86 children was 28.6 µg/dL. The mean blood cadmium level was 0.5 µg/dL, and 15 of 87 children had levels of 1.0 µg/dL or greater. The mean blood lead and blood cadmium levels for the Bartlesville children were the highest of the mean levels for the 19 smelter towns investigated.

In 1977, the Research Triangle Institute conducted a comprehensive exposure assessment of Bartlesville residents which included testing of blood, hair, soil, house dust, interior paint, and tap water (3). For children 1 to 5 years old living near the smelter, 54 of 67 (80.6%) had blood lead levels of 10 µg/dL or greater, 25 of 67 (37.3%) had levels of 30 µg/dL or greater, and 1 of 67 (1.5%) had a level of 80 µg/dL or greater. Twenty-seven of the 67 children (40.3%) tested had blood cadmium levels above 0.2 µg/dL, and 4 of those had levels 1.0 µg/dL or greater. The Research Triangle Institute study also included tests of 341 individuals older than 5 years, and results indicated similar blood lead and cadmium levels to those of the younger children.

Blood lead studies were conducted by Environmental Consultants Laboratory from September 1977 to December 1979 as a part of a class action law suite against the owners of the National Zinc Smelter (4). Blood samples were obtained from 169 individuals (children and adults) who resided within 1.6 kilometers (approximately 1 mile) of the smelter; 53.9 percent of the samples exceeded the 1976-1980 National Health and Nutrition Examination Survey (NHANES) mean blood lead for all ages of 13.9 µg/dL.

In 1991 to 1993, the OSDH[5], with assistance of ATSDR and the Washington County Department of Health, sampled the blood of Bartlesville residents for lead (31). Of the children under 6 years old, 36 of the 246 living in the contaminated area of Bartlesville (14.6%) had blood lead levels of 10 µg/dL or greater. The highest level was 24.0 µg/dL. In contrast, none of the 127 children under 6 who resided in the non-contaminated area of Bartlesville had levels of 10 µg/dL or greater.

b. Evaluation of Blood Contamination

These four sets of data support an association between contaminant levels in blood and living in the area near the smelter. The two sets of data from the 1970s were obtained when there were little or no restrictions on smelter emissions (4). The much higher blood lead levels (80% at 10 µg/dL or greater) identified in the 1970s studies indicate that the smelter emissions had a strong influence on blood levels. This conclusion is further supported by the sampling of house dust, residential soil, and blood in the Research Triangle Institute study, which identified higher levels of cadmium and lead in all three media in the area downwind from the smelter than in areas upwind from the smelter (4). This area is north of the smelter. Parental occupation and lead level in interior paint were not related with blood lead levels. Incidentally, the percentage of homes in Bartlesville with lead in interior paint was similar to percentages in two nearby communities where blood lead levels were much lower.

The results of the 1990s testing, while lower than those from the 1970s, indicate that children living around the smelter have higher blood lead levels than children living elsewhere in Bartlesville (31). Those elevated levels appear to be due, at least partially, to the elevated residential soil lead levels. This determination is based on the follow-up of children with 10 µg/dL or greater blood lead and an association between blood lead levels and soil lead levels.[6]

Additional evidence for an association between children's blood lead levels and lead soil contamination comes from three literature reviews evaluated (32-34). All 3 concluded that soil lead levels of 1,000 mg/kg would increase concentrations in blood by 0.6 to 65 µg/dL, with an average increase of 4-5 µg/dL. This wide range was due to different sources of lead, exposure conditions, and exposed populations. The smallest increases in blood lead were observed in communities with mines or inactive smelters. The health effects associated with such an increase would depend partly on the existing body burden of lead.

c. Toxicology of Lead and Possible Health Consequences from Exposure

Exposure to lead causes a wide range of effects (25). The level of lead in blood is a good measure of recent exposure, and it also correlates well with health effects. Children are especially sensitive to lead, and many of its effects are observed at lower concentrations in children than in adults. Levels of 10 µg/dL and perhaps lower in children's blood have been associated with decreased IQ and impaired hearing and growth. Neurological effects may persist after exposure has ceased and blood lead levels have returned to normal (35). Lead can significantly affect both the reproductive process and the development of the fetus at blood lead levels in a pregnant woman as low as 10 µg/dL. Documented effects include reduced production of sperm, premature birth, and low birth weight. In adults, levels as low as 15 µg/dL are linked to increases in blood pressure and erythrocyte protoporphyrin.

The increased vulnerability of children results from a combination of factors, including the following:

(1) The increased susceptibility of the developing nervous system to the neurotoxic effects of lead,

(2) A higher average rate of soil ingestion among children than among adults,

(3) The greater efficiency of lead absorption in the gastrointestinal tract of children,

(4) Children's greater prevalence of iron or calcium deficiencies, which may exacerbate the toxic effects of lead, and

(5) The ready transfer of lead across the placenta to the developing fetus (36).

For the OSDH/ODEQ study's 36 children with blood lead levels of 10 μg/dL and greater, effects such as slightly decreased IQ, impaired hearing and growth, and decreased Vitamin D metabolism were possible. Whether any of those effects occurred was dependent on the nutritional status and total body burden of lead for each child (25,37). Increased blood lead levels created the possibility of such health effects as decreased hemoglobin synthesis, colic, anemia, kidney damage, and encephalopathy for many of the children in the 1970s Bartlesville studies (25,37).

d. Possible Health Consequences from Exposure to Cadmium

Health effects were possible for those children in the two 1970s studies with blood cadmium levels of 1.0 μg/dL and perhaps lower (24). Kidney dysfunction was identified among workers with blood cadmium levels of 1.0 μg/dL who had been exposed to cadmium for 20 years. Little is known about cadmium exposure's health consequences for children. There is a discussion of the toxicology of cadmium in the Toxicological Evaluation section of this public health assessment.

C. Community Health Concerns Evaluation

The community health concerns identified earlier are addressed as follows:

1. Is the cancer incidence (as the result of occupational and environmental exposures) in the Bartlesville area elevated?

RESPONSE

There was not appropriate cancer incidence data available for the Bartlesville area to allow an answer to this question. However, ATSDR did evaluate cancer mortality data for Washington County. As described in the Health Outcome Data Evaluation section, deaths from multiple myeloma and ovarian cancer were greater than would have been expected from state rates. There is no evidence that cadmium or lead can cause those two cancers.

2. Is the incidence of birth defects in the area elevated? If so, could the increased incidence be caused by the same causes producing birth defects in horses born near the smelter before the smelter used pollution control devices ("smelter colts")?

RESPONSE

This question could not be addressed because of a lack of information. Appropriate birth defect data for the Bartlesville area were not available. Birth record databases identify only those birth defects that can be recognized at birth (40). The developmental effects associated with lead exposure are not diagnosed until well after birth (25). Therefore, birth record data were not obtained.

3. Is the environmental contamination related to behavioral problems of children in the area?

RESPONSE

Lead exposure can cause behavioral problems in young children (25,37). To determine whether a specific child's behavioral problems are linked with lead, it would be necessary to test the child for exposure to lead and, if an elevated level were found, to investigate possible exposure sources, including soil, paint, etc. Through this process, an association between the environmental contamination and a child's behavioral problems could be established.

4. Is Multiple Sclerosis (MS) caused by lead and/or cadmium?

RESPONSE

There is no indication that MS is caused by lead or cadmium (41). MS is a disease which causes the myelin coating around the nerves to disappear over time. This process usually results in a gradual loss of neural function. The average age of onset of MS is about 30 years. Viral agents are suspected as the causative agent for MS, but there is no strong evidence supporting a link with any specific virus. There is no good evidence for an association with any chemical or with radiation.

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Agency for Toxic Substances and Disease Registry, 1825 Century Blvd, Atlanta, GA 30345
Contact CDC: 800-232-4636 / TTY: 888-232-6348

PUBLIC HEALTH ASSESSMENT

NATIONAL ZINC COMPANY
BARTLESVILLE, WASHINGTON COUNTY, OKLAHOMA

CONCLUSIONS

Based on the available information, the Agency for Toxic Substances and Disease Registry (ATSDR) concludes that the proposed National Zinc Company National Priorities List site is a public health hazard because individuals are being exposed to cadmium, lead, and zinc surface soil contamination at levels that could result in adverse health effects. Children are more likely than adults to ingest surface soil contamination. Studies have demonstrated that the children living in the area of surface soil contamination have higher blood lead levels than the levels of children living outside the area of contamination. Individuals who are exposed to the surface soil contamination may experience proteinuria (i.e., protein in urine which is evidence of mild kidney damage); decreased metabolism of vitamin D; impaired hearing and growth; and slightly decreased IQs. Remediation of the contaminated soils should remove this public health hazard.

Environmental monitoring studies conducted in the past indicate that individuals may have been exposed to cadmium, lead, zinc, and sulfuric acid at levels which could result in adverse health effects. The 1970s blood cadmium and blood lead studies demonstrated that children living near the smelter were exposed to elevated levels of cadmium and lead. Individuals who were exposed in the past to the air emissions from the smelter and the surface soil contamination could have experienced decreased hemoglobin synthesis, anemia, increased blood pressure, impaired hearing and growth, slightly decreased IQs, and encephalopathy. Cadmium air emissions from the National Zinc Company smelter could have increased lifetime Bartlesville residents' risk of developing cancer. Exposure to sulfuric acid air emissions could have resulted in irritation to the eye, nose, throat, lung, and skin at the time of exposure, but does not pose a current threat to the health of individuals in this area.

Analysis of samples taken from groundwater monitoring wells on and near the Zinc Corporation of America facility indicate that the groundwater contamination found on the facility has not migrated very far. No drinking water wells are known to exist within the area of contamination. Therefore, it is unlikely that any drinking water wells have been contaminated with facility-related metals.

Results of ambient-air monitoring data indicate that the interim dust control measures at the residual piles are preventing significant air emissions. ATSDR scientists are concerned that air emissions from the residual piles at the Zinc Corporation of America could occur whenever the piles are disturbed or the interim measures are not continued.

Information on the incidence of cancer and birth defects is not available for the Bartlesville area. The Oklahoma Department of Health is presently compiling the data.

RECOMMENDATIONS

The Agency for Toxic Substances and Disease Registry (ATSDR) recommends the following:

1) Continue to clean up the contaminated soils in residential areas.

2) Continue to control air emissions from the residual piles.

The proposed National Zinc Company National Priorities List (NPL) site, Bartlesville, Washington and Osage Counties, Oklahoma, has been evaluated by the ATSDR Health Activities Recommendation Panel (HARP) to determine what future health activities are recommended at this site. Because human exposure to hazardous substances associated with the site has occurred, an evaluation of adverse health outcomes that may be related to past exposures is recommended. In addition, an evaluation of health statistics should be conducted to the extent possible. A site specific environmental health education program is recommended to advise public health professionals and local medical community of the nature and possible consequences of exposure to contaminants at the proposed National Zinc Company NPL site. ATSDR provided health education during the public comment period of this Public Health Assessment. As far as practical, ATSDR and the Oklahoma State Department of Health (OSDH) will cooperate in conducting these activities.

PUBLIC HEALTH ACTIONS

The Public Health Action Plan (PHAP) for the proposed National Zinc Company National Priorities List site is a description of actions the Agency for Toxic Substances and Disease Registry (ATSDR), the U.S. Environmental Protection Agency (EPA), the Oklahoma State Department of Health (OSDH), and the Oklahoma Department of Environmental Quality (ODEQ) will take at the site after the public health assessment is complete. The purpose of the PHAP is to ensure that this public health assessment identifies public health hazards and includes a plan of action to stop or prevent harm to people from their exposure to hazardous substances in the environment. ATSDR, EPA, OSDH, and ODEQ are committed to this plan and will ensure that it is carried out.

A. Public Health Actions Taken

OSDH and ODEQ -- with ATSDR's support -- have conducted blood lead monitoring of Bartlesville children. In addition, OSDH and ATSDR have conducted lead health education programs for the local public health professionals, members of the local medical community, and the general public.

EPA has remediated the contaminated surface soils at the playgrounds and school grounds within Bartlesville.

EPA has issued a Resource Conservation and Recovery Act (RCRA) corrective action order requiring the owners of the Zinc Corporation of America facility to develop and implement a plan to clean up the environmental contamination at the facility.

EPA has issued an Unilateral Administrative order requiring the potentially responsible parties to perform a removal action in residential areas where the soil contamination exceeds 1,500 milligrams of lead per kilogram of soil (mg/kg) and/or 90 mg/kg for cadmium. The removal actions required by the EPA Unilateral Administrative order began in March 1994 and continued until the end of 1994. A community relations office was established by the potentially responsible parties to answer questions concerning the on-going removal action.

The administration of the remediation of the site has been delegated to ODEQ in lieu of finalizing the site on the National Priorities List (NPL) (a.k.a., "Superfund"). The State Pilot Delegation Program was approved by EPA on March 15, 1994.

Also on March 15, 1994, ODEQ and the potentially responsible parties signed a Consent Agreement and Final Order.

The Remedial Investigation/Feasibility Study prepared by the potentially responsible parties was made available to the public on July 1, 1994, and finalized on September 1, 1994.

On September 1, 1994, a draft Proposed Plan for remedial action was issued by ODEQ.

ATSDR provided health education during the public comment period (September 21, 1994 through November 20, 1994) of this public health assessment.

On December 13, 1994, ODEQ issued a Record of Decision (ROD) for Operable Unit One of the proposed National Zinc Company NPL site. The ROD presents the selected remedial action to reduce the risks to human health associated with exposure to the contaminated materials.

B. Public Health Actions Planned

EPA and ODEQ will continue to ensure the remediation of the site-related environmental contamination and the control of air emissions from the residual piles.

As required by the ROD for Operable Unit One, blood lead studies will be conducted annually throughout the remedial action. In addition, comprehensive blood lead studies will be conducted two years and five years after the completion of the remedial action in residential areas. These studies will be used to assure that the selected remedial action is protective of public health.

ATSDR and OSDH will conduct an evaluation of adverse health outcomes that could be related to past exposures to site-related contaminants. In addition, an evaluation of health statistics should be conducted to the extent possible.

ATSDR and OSDH will provide health education to advise local public health professionals and members of the local medical community of the nature and possible consequences of exposure to contaminants at the proposed National Zinc Company NPL site.

EPA and ODEQ will update ATSDR on remedial activities at the proposed National Zinc Company NPL site. ATSDR will assist EPA, ODEQ, and OSDH with public health activities at this site.

PREPARERS OF REPORT

Sven E. Rodenbeck, P.E.
Environmental Engineer Consultant
Superfund Site Assessment Branch
Division of Health Assessment and Consultation

John R. Crellin, Ph.D.
Environmental Health Scientist
Superfund Site Assessment Branch
Division of Health Assessment and Consultation

ATSDR REGIONAL REPRESENTATIVE

Jennifer L. Lyke
Environmental Protection Specialist
ATSDR Region VI

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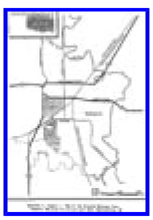
Department of Health and Human Services
Agency for Toxic Substances & Disease Registry

PUBLIC HEALTH ASSESSMENT

NATIONAL ZINC COMPANY
BARTLESVILLE, WASHINGTON COUNTY, OKLAHOMA

APPENDICES

Appendix 1
Figure 1



Appendix 1, Figure 1 - Map of the Proposed National Zinc Company National Priorities List Site, Bartlesville, OK

Appendix 2
Health Comparison Values

Health comparison values for the Agency for Toxic Substances and Disease Registry (ATSDR) public health assessments are contaminant concentrations that are found in specific media (air, soil, and water) and that are used to select contaminants for further evaluation. The values provide guidelines that are used to estimate a dose at which health effects might be observed. The health comparison values were developed by using the most conservative assumptions (i.e., worse case). For example, soil health comparison values are developed for children who exhibit pica behavior. Soil ingestion in pica children greatly exceeds the soil ingestion rate for the normal population. Health comparison values used in the Environmental Contamination and Other Hazards and the Public Health Implications sections of this public health assessment are listed and described below.

Cancer Risk Evaluation Guides (CREGs) are estimated contaminant concentrations that would be expected to cause no more than one excess cancer in a million (10E-6) persons exposed over a lifetime. CREGs are calculated from EPA's cancer slope factors.

Environmental Media Evaluation Guides (EMEGs) are based on ATSDR's minimal risk levels (MRLs) and factor in body weight and ingestion or inhalation rates. Reference Dose Media Evaluation Guides (RMEGs) are the same as EMEGs, except that they are based on the U.S. Environmental Protection Agency (EPA) reference doses (RfDs).

An MRL is an estimate of daily human exposure to a chemical (in mg/kg/day) that is likely to be without an appreciable risk of deleterious effects (noncarcinogenic) over a specified duration of exposure. MRLs are based on human and animal studies and are reported in the ATSDR Toxicological Profiles for acute (≤ 14 days), intermediate (15-365 days), and chronic (≥ 365 days) exposures.

EPA's RfD is an estimate of the daily exposure to a contaminant that is unlikely to cause adverse health effects. However, RfDs do not consider carcinogenic effects.

Appendix 3 - Environmental Exposure Pathways
Tables 1 and 2

Appendix 3, Table 1 - Completed Environmental Exposure Pathways at the Proposed National Zinc Company National Priorities List Site

Pathway Name	Point of Exposure	Route of Exposure	Exposed Population	Time of Exposure	Contaminants of Concern	Estimated Exposed Population
Surface Soil	The Smelters and Surrounding Residential Areas	Ingestion Inhalation Skin Contact	Smelter Workers and Residents near the Smelter	Past Present Future	Cadmium Lead Zinc	More Than 5,000
Air	The Smelters and Surrounding Residential Areas	Inhalation Ingestion Skin Contact	Smelter Workers and Residents near the Smelter	Past	Cadmium Lead Zinc Sulfuric Acid	More Than 5,000

Appendix 3, Table 2 - Potential Environmental Exposure Pathways at the Proposed National Zinc Company National Priorities List Site

Pathway Name	Point of Exposure	Route of Exposure	Exposed Population	Time of Exposure	Contaminants of Concern	Estimated Exposed Population
Sediment and Surface Water	The Smelters and Ditches off the Facility	Ingestion Inhalation Skin Contact	Smelter Workers and Residents near the Smelter Who Visit the Ditches	Past Present Future	Arsenic Cadmium Lead Manganese Nickel Zinc	Unknown
Biota (Plants)	Residential Areas	Ingestion Skin Contact	Residents near the Smelter with	Past Present Future	Cadmium Lead Zinc	Unknown

			Gardens			
Groundwater	Former Wells within a Three Mile Radius of the Smelters and Wells Beyond the Radius	Ingestion Inhalation Skin Contact	Residents	Past Present Future	Arsenic Cadmium Lead Manganese	Unknown
Residual Piles and Subsurface Soils	The Smelter and Surrounding Residential Areas	Inhalation Ingestion Skin Contact	Smelter Workers and Residents Near the Smelter	Present Future	Arsenic Cadmium Lead Manganese Nickel Zinc	Unknown

Appendix 4 - Comparison of Estimated Exposure Doses to Health Guidelines

TABLE 1 - COMPARISON OF ESTIMATED EXPOSURE DOSE TO HEALTH GUIDELINES FOR INGESTION OR INHALATION*				
CONTAMINANT	**EXPOSURE PATHWAY**	**HEALTH GUIDELINE**	**SOURCE**	**HEALTH GUIDELINE EXCEEDED BY EXPOSURE DOSE**
Cadmium	Residential Surface Soil	0.0007 mg/kg/day	MRL#	YES
Cadmium	Ambient Air	0.0006 $\mu g/m^3$	CREG@	YES
Zinc	Residential Surface Soil	0.3 mg/kg/day	RfD&	YES, but only for children and pica children
* - An explanation of how exposure doses are calculated can be found after this Table. # - MRL is Minimal Risk Level (chronic). @ - CREG is Cancer Risk Evaluation Guides. & - RfD is reference dose. mg/kg/day - milligram of contaminant per kilogram of body weight per day. $\mu g/m^3$ - micrograms of contaminant per cubic meter of air.				

Calculation of Exposure Doses for Soil Ingestion

The exposure doses for soil ingestion were calculated in the following manner. The maximum concentration for a contaminant was multiplied by the soil ingestion rate for adults, 0.0001 Kg/day; children, 0.0002 Kg/day; or pica children, 0.005 Kg/day. (The habit of ingesting large amounts of soil is called pica.) This product was divided by the average weight for an adult, 70 Kg (154 pounds) or for a child, 10 Kg (22 pounds). Those calculations assume that there is frequent daily exposure to soil contaminated at the maximum level. A qualitative summary of these results can be found in the table above.

Appendix 5 - Response to Comments Received during the Public Comment Period for the National Zinc Company Public Health Assessment

The National Zinc Company (NZC) Public Health Assessment was available for public review and comment from September 21, 1994, through November 20, 1994. The Public Comment Period was announced in the Tulsa World and the Bartlesville Examiner-Enterprise. Copies of the public health assessment were made available for review at the Westside Community Center and the Bartlesville Public Library. In addition, the public health assessment was sent to nine persons or organizations. On October 13, 1994, the Agency for Toxic Substances and Disease Registry (ATSDR) held a Public Meeting at the Westside Community Center. The Public Meeting was arranged so that the public could discuss the findings of the NZC Public Health Assessment with ATSDR and to permit the public to provide ATSDR with any comments.

During the Public Comment Period, ATSDR received comments from two individuals, two consulting firms, the Oklahoma State Department of Health (OSDH), and the Oklahoma Department of Environmental Quality (ODEQ). Comments and ATSDR responses are summarized below. The comment letters can be requested from ATSDR through the Freedom of Information Act.

Comment: I would like to request an additional 30 days beyond the October 20, 1994, date to make a public comment regarding the Health Assessment of NZC.

Response: ATSDR extended the Public Comment Period for the NZC Public Health Assessment until November 20, 1994.

Comment: Since the Resource Conservation and Recovery Act (RCRA) and Superfund are separate divisions, but both involved in cleanup recommendations and activities, there needs to be some cooperation within U.S. Environmental Protection Agency (EPA) to co-ordinate (or at least interpret for the public) what their current and future recommendations will be for both divisions. Citizens should have some input on RCRA recommendations as they do with Superfund.

Response: Because ATSDR is an independent non-regulatory agency separate from the EPA and the ODEQ, we can not direct these agencies to coordinate their activities. However, ATSDR will submit your comment and concern to the appropriate individuals within EPA and ODEQ.

Comment: Footnote 5 on page 29 should be revised to read as follows: "The Maternal and Child Health Service, Oklahoma State Department of Health (OSDH), conducted the blood lead testing in collaboration with the OSDH environmental unit. The OSDH environmental unit became a part of the Oklahoma Department of Environmental Quality in 1993. This unit continues to oversee the overall community activities."

Response: The public health assessment has been revised accordingly.

Comment: The response to question 4, "Is Multiple Sclerosis (MS) caused by lead and/or cadmium?", goes into detail that is not pertinent to the issue being discussed. OSDH would like to recommend that a significant portion of this response be deleted.

Response: The public health assessment has been revised as recommended.

Comment: Change the last sentence of the first full paragraph on page 33 to read as follows:

> Exposure to sulfuric acid air emission could have resulted in irritation to the eye, nose, throat, and skin at the time of exposure, but does not pose a current threat to the health of individuals in this area.

Response: The public health assessment has been revised as recommended.

Comment: Summary, paragraph three, line eight. The ODEQ believes that the use of "National Zinc Site" or " historical smelter operations" should be utilized to avoid confusion as to the current status of the Zinc Corporation of America facility which is not included in the National Zinc Company CERCLIS site.

Response: The public health assessment has been revised to avoid the confusion.

Comment: Page 3, paragraph five, line four. The use of the word "safe" would appear to inappropriate; we would suggest substitution by "acceptable."

Response: Based upon current scientific information, the blood lead levels detected in the Bartlesville children were above levels which are known not to be safe (i.e., adverse health effects could occur) or acceptable by current guidelines. ATSDR prefers the term "safe" because it not only indicates that health officials have determined that these levels are not acceptable but that adverse health effects could occur.

Comment: Page 5, paragraph two. Dr. Edd Rhoades, chief of Pediatrics, Oklahoma State Department of Health conducted medical education regarding lead exposure during 1992.

Response: This information has been added to the public health assessment. Thank you for providing it to ATSDR.

Comment: Page 5, paragraph three. Discussion of actions regarding the "National Zinc Site" under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and actions regarding the Zinc Corporation of America facility under RCRA should be separated to avoid confusion.

Response: The public health assessment has been revised as recommended.

Comment: Page 8, paragraph two, last sentence. Appendix 2 contains no listing of the health comparison values; these appear in Tables 1, 2, and 3.

Response: The public health assessment has been revised to avoid the confusion.

Comment: Page 21, paragraph one. The value being referred to as "exposure dose" is in actuality an "exposure level" or "estimated chronic intake" rather than a dose. The use of the term "dose" is misleading.

Response: The use of the term "exposure dose" is being used in accordance with the ATSDR Public Health Assessment Guidance Manual.

Comment: Page 21, paragraph three. The statement that there are no health guidelines for exposure to lead in soil is inaccurate. EPA and ODEQ have set action guidelines for interpretation of lead concentrations in soil of 500 ppm in residential areas. The underlying basis for this guideline is the protection of human health.

Response: ATSDR has not been able to establish a minimal risk level (MRL) for lead because a threshold has not yet been defined for the most sensitive effects of lead (i.e., neurotoxicity). EPA has not been able to establish a reference dose (RfD) for the same reason. The action level discussed by the commentator was established to help site investigators determine whether additional soil sampling should be conducted at a site. The guidelines do not establish any health guidance and should not be used to predict health outcomes.

Comment: Page 22, paragraph one under a. Cadmium, Soil. The soil concentration presented as acceptable (non-pica children) for cadmium, 375 parts per million (ppm), is considerably above the risk based level proposed for residential areas by the ODEQ in the Proposed Plan (100 ppm) which is criticized by ATSDR in their comments on the ODEQ Proposed Plan, dated October 12, 1994. It would appear that ATSDR is inconsistent in what is considered to be an acceptable level of cadmium in soil.

Response: In the latter part of the paragraph cited by the commentator, ATSDR states:

> "For small children who ingest large amounts of soil (i.e., pica children), the lowest effects level is exceeded when the cadmium level exceeds 15 mg/kg (sic ppm)."

In ATSDR's comments to ODEQ concerning the Proposed Plan, ATSDR did not recommend a cleanup level. ATSDR only provided ODEQ with it's opinion on what factors should be considered and evaluated when developing a cleanup level. Therefore, ATSDR does not believe it is being inconsistent.

Comment: Page 23, paragraph one (Air) and paragraph five (Risk of Cancer). The maximum air concentration (0.61 micrograms of cadmium per cubic meter of air [$\mu g/m^3$]) cited was determined to be an invalid sample by EPA and ODEQ. Therefore, the use of an invalid sample point to determine risk of cancer is inappropriate. We would suggest the use of the average air value or presentation of risk by a range based on the range of concentrations measured in the area.

Response: The public health assessment has been revised to correct this misunderstanding and to clarify the agency's opinion

Comment: Page 23, paragraph five (Risk of Cancer). The structure of the paragraph is misleading. The reference to the cadmium smelter worker study which identified a two fold increase in the rate of lung cancer could be read to refer to the historical smelter operation in Bartlesville. This not the case. The paragraph should be rewritten to clarify that the data from the study are not reflective of the concentrations associated with the National Zinc site.

Response: The public health assessment has been revised to avoid the confusion.

Comment: Page 24, c. Sulfuric Acid. The discussion regarding the fact that current exposures to sulfuric acid are not present in the area and that health consequences related to the 1977 releases would not be occurring in the present needs to be strengthened here and in the Summary and Conclusions Sections.

Response: This issue was also raised by another commentator. The public health assessment has been revised as recommended.

Comment: Information concerning the 1977 through 1979 Environmental Consultants Laboratory blood lead study was not included in the public health assessment.

Response: This information has been added to the public health assessment (i.e., Background and Review of Blood Contaminant Data sections). Thank you for bringing this information to the attention of the Agency.

Comment: Page 32, response to questions 4. The inclusion of the material relating multiple sclerosis and latitude is misleading. It is not clear what significance this material has to the question that was posed and the situation in Bartlesville.

Response: This issue was also raised by another commentator. The public health assessment has been revised as recommended.

Comment: Page 34, A. Public Health Actions Taken. The commentator provided ATSDR with information which should be included in this section.

Response: ATSDR appreciates receiving this information and has included it in the appropriate sections of the public health assessment.

Comment: The inclusion of zinc as a contaminant of concern is problematic. In the baseline risk assessment prepared for EPA by CH2M Hill, the Remedial Investigation/Feasibility Study (RI/FS) and the proposed plan have all indicated that the contaminants of concern at the site included lead, cadmium, and arsenic. Zinc has been determined to be of significance as an ecological concern.

Response: In accordance with the ATSDR Public Health Assessment Guidance Manual health comparison values are used to determine which contaminants should be looked at more closely in the public health assessment. As stated in the Environmental Contamination and Other Hazards section:

"A contaminant is selected for further evaluation if the contaminant concentration in a valid environmental sample exceeds comparison values. The presence of a contaminant on the lists in the tables of this section does not mean that either exposure to the contaminant or adverse health effects has occurred or will occur. Inclusion in the list indicates only that the potential for human exposures to the selected contaminants and the potential for adverse human health effects as a result of any exposures to the selected contaminants will be discussed in more detail in later sections of this Public Health Assessment."

ATSDR evaluates the possible toxicological effects of zinc in the Toxicological Evaluation section of the public health assessment. In that section, ATSDR states that there is some possibility of noncarcinogenic health effects for children exposed to zinc in residential soil. However, it is uncertain that these health effects would occur because of the different zinc metabolism between adults and children.

Comment: ATSDR has failed to consider the off-site groundwater monitoring data that indicate groundwater is not a potential exposure pathway. The commentator provided ATSDR with copies of their investigation reports.

Response: ATSDR appreciates receiving the off-site groundwater monitoring data. The data will be included in the public health assessment and the conclusions and recommendation will be changed as appropriate.

It should be noted that the investigation reports were submitted to EPA just before and during the Public Comment Period for the NZC Public Health Assessment. Therefore, this information was not available to ATSDR in order to develop the public comment release public health assessment.

Comment: Air monitoring data show that dust from the residue piles is not a threat to public health. The commentator provided ATSDR with copies of their investigation report.

Response: ATSDR appreciates receiving the air monitoring data. The data will be included in the public health assessment and the conclusions and recommendation will be changed as appropriate.

It should be noted that the investigation reports were submitted to EPA just before and during the Public Comment Period for the NZC Public Health Assessment. Therefore, this information was not available to ATSDR in order to develop the public comment release public health assessment.

Comment: ATSDR has overestimated risk, casting doubt on it's conclusions and recommendations. The commentator made eight specific points.

Response: ATSDR does not believe it has overestimated the possible risk associated with the NZC Site. ATSDR will respond to each of the commentators points.

Comment: Point 1. An overly conservative target risk level for use in evaluating need for remediation.

Response: The target risk levels cited by the commentator are the health comparison values in the public health assessment. In accordance with the ATSDR Public Health Assessment Guidance Manual health comparison values are used to determine which contaminants should be looked at more closely in the public health assessment. As stated in the Environmental Contamination and Other Hazards section:

"A contaminant is selected for further evaluation if the contaminant concentration in a valid environmental sample exceeds comparison values. The presence of a contaminant on the lists in the tables of this section does not mean that either exposure to the contaminant or adverse health effects has occurred or will occur. Inclusion in the list indicates only that the potential for human exposures to the selected contaminants and the potential for adverse human health effects as a result of any exposures to the selected contaminants will be discussed in more detail in later sections of this Public Health Assessment."

ATSDR evaluates the possible toxicological effects for each of the contaminants selected (i.e., above health comparison values) in the Toxicological Evaluation section of the public health assessment. In this section, ATSDR discusses the possible health effects and the uncertainty of the toxicological information.

The ATSDR Minimal Risk Levels (MRLs) and Cancer Risk Evaluation Guides (CREGs) used in this public health assessment come from the chemical specific ATSDR Toxicological Profile. Each Toxicological Profile is peer reviewed and released for public comment. Each Toxicological Profile describes how each MRL and CREG is developed.

It is important to note that ATSDR did not base its conclusions and recommendations solely on the toxicological information. The blood lead studies have consistently shown that children living near the smelter have blood lead levels above the Centers for Disease Control and Prevention guidelines.

Comment: Point 2. A flawed RfD for zinc, especially as applied to infants and children.

Response: ATSDR agrees that there is some uncertainty associated with the zinc RfD as it applies to infants and children. In the toxicological section, ATSDR states that there is some possibility of noncarcinogenic health effects for children exposed to zinc in residential soil. However, ATSDR is uncertain whether these health effects would occur because of the different zinc metabolism between adults and children (page 24 of the public comment release public health assessment).

Comment: Point 3. Use of a single maximum value for a metal in soil to estimate exposure.

Response: ATSDR did not only use a single maximum value for estimating exposure. In the Toxicological section, ATSDR indicates at what environmental soil concentration exposures would exceed an ATSDR Minimal Risk Level (MRL) or EPA Reference Dose (RfD). For example, on page 22 of the public comment release public health assessment ATSDR states:

"Soil concentrations of cadmium of 375 mg/kg and greater result in exposure doses for small children (10 kilograms [Kg]/22 lbs) that exceed the lowest observed effect level in humans of 0.0075 milligrams of cadmium per kilogram body weight per day (mg/kg/day). For small children who ingest large amounts of soil (i.e., pica children), the lowest effects level is exceeded when the cadmium level exceeds 15 mg/kg. Cadmium soil levels in the community around the Zinc Corporation facility vary from 0.2 - 1,372 mg/kg."

Comment: Point 4. The inclusion of the pica child to evaluate chronic effects.

Response: In accordance with the ATSDR Public Health Assessment Guidance Manual, the possible toxicological effects for all people living and working at a site, including sub-populations (i.e., pica children), should be discussed in a public health assessment. ATSDR agrees that there is some uncertainty as to how much and how long a child ingests soil. As indicated in the response to sub-comment number 3, even non-pica children may be exposed to cadmium in soil at levels of public health concern. Therefore, ATSDR conclusions are not based solely on the possible exposures to pica children.

Comment: Point 5. Lack of consideration of the bioavailability of metals in soil.

Response: Bioavailability of metals in soils is an issue that needs to be considered when evaluating the toxicity of metals found in soils. However, bioavailability is dependent upon site-specific conditions (e.g., chemical species of the soils and metals, the nutritional status of the exposed population, etc.).

ATSDR is familiar with the site-specific bioavailability study conducted by PTI Environmental

Services. However, this study does have some limitations. The primary limitation is that the rodent is not the best model for representing bioavailability in a child. The pig is thought to be a better animal model for metal bioavailability studies (Weis CP and Lavelle JM. Characteristics to consider when choosing an animal model for the study of lead bioavailability. Chemical Speciation and Bioavailability. 1991;3(3-4):113-119.). In addition, the regimen of introducing the contaminants with the feed may alter bioavailability. A child may ingest soil or dust on an empty stomach. This would result in more metal uptake. The animal model also does not represent a child or infant with poor nutrition, a possible situation at the NZC site. Therefore, ATSDR decided that there is not any good site-specific bioavailability data.

Most of the toxicological studies cited by ATSDR reported the exposure dose (dose in the feed) given to the animals. In addition, the epidemiologic worker studies cited by ATSDR reported the environmental concentrations (exposure doses) that the workers were exposed to. Given the uncertainty surrounding the bioavailability of metals and the differences between animal and human metal uptake, ATSDR compared the exposure dose of the animals and the exposure dose of the workers in the epidemiologic studies to the exposure doses that the people near the NZC site may experience. In addition, ATSDR relied upon the result of the blood lead and blood cadmium studies. These studies indicate that people near the site have higher blood lead and blood cadmium levels than people farther away from the site. ATSDR came to its conclusions by using this weight of evidence approach.

Comment: Point 6. Lack of consideration of antagonistic interactions between cadmium and zinc.

Response: ATSDR has added a new sub-section to the public health assessment which discusses the interaction between cadmium, lead, and zinc. The information is based upon the ATSDR Toxicological Profiles for cadmium, lead, and zinc.

Comment: Point 7. Failure to incorporate site-specific data on the transfer of metals from soil to dust. Specifically, using the default values in the EPA Integrated Exposure Uptake Biokinetic Model for lead in children (IEUBK).

Response: ATSDR is very familiar with the IEUBK. ATSDR's believes that the IEUBK should not be used to predict health outcomes. In addition, ATSDR believes that the IEUBK should not be used as the sole basis for selecting the lead cleanup level at this site or any other site. The IEUBK is not validated for all sites and situation and does not take into account all of the health aspects needed to be considered when trying to determine possible health outcomes or when selecting a soil cleanup level. For example; the type and variation of soil cover within the area, the nutritional status of the population within the area, and the possible interactions between lead and the other site-related contaminants may all influence exposure and need to be considered and evaluated.

Comment: Point 8. No consideration of results from recent studies demonstrating a minimal, if any, impact on blood lead levels after soil removal. The commentator specifically cited the EPA's Three-City Lead study.

Response: ATSDR is familiar with the Three-City Lead study. Although the study was very large and well conducted, it does have some limitations. The main limitation is the study did not determine where the study children played and spent their time outside. Therefore, the study may have a significant exposure bias. ATSDR believes the Three-City Lead study is a significant step in understanding the relationship between lead poisoning and the sources of lead. However, additional studies are needed to confirm the Three-City Lead study results.

The results of the Three-City Lead study can not be directly related to the situation in Bartlesville. As discussed above, various site-specific factors influence the bioavailability of lead and other metals. The specific situations at the three cities in the EPA study (Baltimore, Boston, and Cincinnati) are different from Bartlesville (e.g., the NZC smelter).

Comment: The draft public health assessment is irrelevant and misleading. The draft public health assessment was issued out of sequence to the RI/FS report. Its' conclusions conflict with those in the Proposed Plan.

Response: ATSDR does not believe the public health assessment is irrelevant and misleading. As required by the CERCLA, as amended by the Superfund Amendments and Reauthorization Act (SARA), ATSDR must conduct a public health assessment within one year of a site being proposed for listing on the National Priorities List (NPL) (a.k.a., "Superfund"). In accordance with ATSDR's procedures, an initial release public health assessment for the proposed National Zinc Company site was completed one year after the proposed listing. The initial release was reviewed by EPA and the State of Oklahoma.

ATSDR is not aware of any conflict between the public health assessment and the Proposed Plan to clean-up the NZC site. The public health assessment concludes and recommends that the site should be remediated. The Proposed Plan describes remedial action alternatives considered for addressing the elevated metal concentrations in the soil at the NZC site and identifies the remedial action selected by the ODEQ. The public health assessment does not recommend how and to what extent the site should be remediated.

Comment: The document should be withdrawn or significantly revised. We strongly recommend that the draft public health assessment either be withdrawn or be revised to focus only on the evaluation of epidemiological data in response to community health concerns. The document should simply refer the reader to the EPA baseline risk assessment and the ODEQ Proposed Plan.

Response: ATSDR has revised the NZC Public Health Assessment to include the groundwater and ambient air monitoring data provided by two commentators. These additional data did not change ATSDR's major conclusion that the NZC site is a public health hazard.

As required by the CERCLA, as amended by the SARA, an ATSDR public health assessment is required to evaluate the nature and extent of contamination, pathways of human exposures, and the size and susceptibility of communities within the likely pathways. In order to comply with this congressional mandate, ATSDR must conduct its' own evaluation. ATSDR can not simply refer the reader to other reports. This public health assessment was conducted in accordance with the ATSDR Public Health Assessment Guidance Manual.

Comment: The draft public health assessment should have been issued before the public comment period for the RI/FS and certainly before issuance of the ODEQ's Proposed Plan.

Response: On May 15, 1994, ATSDR issued the initial release public health assessment for the proposed NZC NPL site. In accordance with ATSDR procedures, the initial release completed ATSDR's statutory requirements under CERCLA. Both EPA and ODEQ were provided copies of the initial release prior to the release of the EPA risk assessment or the ODEQ Proposed Plan.

ATSDR would have preferred to have issued the public comment release of this public health assessment prior to the draft RI/FS. However, the accelerated investigation and cleanup of this site, which ATSDR fully supports, resulted in the public comment release being issued sightly after the draft RI/FS was released.

Comment: ATSDR should explain the inconsistencies and errors in the draft public health assessment to the community. Specific examples were provided by the commentator.

Response: ATSDR will respond, below, to each of the specific comments.

Comment: Page 1, last paragraph, 2nd bullet. Evaluation of groundwater as a threat to human health should not be considered as a recommended action.

Response: Based upon the data submitted by another commentator, ATSDR agrees that the groundwater monitoring recommendation is not necessary. The public health assessment has been revised accordingly.

Comment: Page 4, 4th paragraph, last sentence. EPA removed soils from 25 (not 29) high access areas and from 10 (not 11) residences.

Response: The NZC Public Health Assessment has been revised accordingly.

Comment: Page 5, 3rd paragraph, 2nd sentence. This sentence regarding finalization of NPL listing is incorrect.

Response: The sentence has been deleted from the public health assessment.

Comment: Page 5, 5th paragraph, 3rd sentence. Final cleanup levels were not presented in EPA's risk assessment but in the Proposed Plan by ODEQ based on information presented in EPA's risk assessment and the RI report.

Response: The public health assessment has been revised accordingly.

Comment: Page 8, 3rd full paragraph, 1st sentence. ATSDR did not evaluate "... all available environmental monitoring data (1971 to present)." That is the crux of the problem.

Response: ATSDR was not provided a copy of the RI/FS until September 14, 1994. The public health assessment was issued on September 7, 1994. The relevant data in the RI/FS has been added to the public health assessment.

Comment: Page 17, 1st paragraph, 2 sentence. This sentence is incorrect and indicates careless interpretation of data. Cadmium and lead could not have been discharged from the smelter as indicated by the 1977 and 1992 ambient air data because smelter discharges ceased after 1976.

Response: As required by the Emergency Planning and Community Right-to-Known Act of 1986, the owners of the smelter reported to EPA that the Zinc Corporation of America released to the air an average of 3,429 pounds of lead, 1,474 pounds of cadmium, and 23,600 pounds of zinc each year for the years 1987 to 1991. This information is presented and discussed in the public comment release public health assessment.

Comment: Page 18, last paragraph, 2nd sentence. This sentence is not correct. The RI data indicated that garden soils had significant lower concentrations of arsenic, cadmium, lead, and zinc than soils from the same yard.

Response: This information will be incorporated into the public health assessment. This part of the public health assessment discusses the **potential** exposure pathways. Although this information indicates that the gardens sampled to date do not appear to have significant metal concentrations, it does not preclude that gardens in the past could have had significant metal concentrations which could have been taken-up by plants.

Comment: Page 19, 1st paragraph. Analysis of soil samples near the Caney River are not particularly relevant to sediments in the Caney River downstream of Eliza Creek. The facility ditch sediment sample referred to in the draft public health assessment (Table 1) is not from "... local drainage ditches near the Caney River."

Response: Nowhere in this paragraph does ATSDR refer to the sediment data contained in Table 1. This paragraph discusses the sediment data taken in Eliza Creek and in Caney River. Table 1 clearly states that the environmental data presented was taken from locations at the Zinc Corporation of America.

This paragraph has been revised to clearly state how the agency came to its conclusion. The data presented in the RI will also be included in this discussion.

Comment: Page 22, Section 2. The possibility of health consequences. These evaluations for cadmium and zinc are preliminary, screening level evaluations that are superseded by the more exhaustive, site-specific analysis in the RI.

Response: This part of the public health assessment was developed in accordance with the ATSDR Public Health Assessment Guidance Manual.

Comment: Page 23, 5th paragraph. Regarding the cancer risk associated with cadmium inhalation, it is important to note that no single individual will be exposed to the maximum observed cadmium concentration (0.61 $\mu g/m^3$) for a lifetime.

Response: This section of the public health assessment has been revised to clarify this issue.

Comment: Page 23, 6th paragraph and page 24, 1st full paragraph. The inclusion of zinc as a contaminant of concern is problematic. A flawed RfD for zinc was used and applied to infants and children. ATSDR did not consider the antagonistic interactions between cadmium and zinc.

Response: ATSDR agrees that there is some uncertainty associated with the zinc RfD as it applies to infants and children. In the toxicological section, ATSDR states that there is some possibility of noncarcinogenic health effects for children exposed to zinc in residential soil. However, ATSDR is uncertain that these health effects would occur because of the different zinc metabolism between adults and children (page 24 of the public comment release public health assessment).

ATSDR has added a new sub-section to the public health assessment which discusses the interaction between cadmium, lead, and zinc. The information is based upon the ATSDR Toxicological Profiles for cadmium, lead, and zinc.

Comment: Page 28, 4th paragraph. The only recent body tissue data available are for lead, consequently there is no evidence that site-related cadmium exposures are occurring at the present time. Moreover, the results of a body tissue monitoring study recently conducted by ATSDR in Palmerton, Pennsylvania suggests that significant cadmium exposures are not currently occurring in Palmerton. Because of the similar histories of the two sites and because the environmental cadmium exposures would have been significantly less in Bartlesville, the results of the ATSDR study in Palmerton strongly indicate that significant cadmium exposures are not currently occurring in Bartlesville.

Response: The public health assessment has been revised to clearly indicate that there is no body tissue data for cadmium.

The ATSDR study in Palmerton found significantly higher urine cadmium level in people from the target area than in the comparison area (ages 40 through 75). ATSDR was not able to determine whether this difference was due to past or current exposures. The results of the Palmerton study can not be directly related to the situation in Bartlesville. The demographic make-up of Palmerton is different than Bartlesville. In addition, Bartlesville has a different soil matrix than Palmerton.

Comment: Page 29, 5th paragraph. In explaining the wide range of increases in blood lead levels associated with lead in soil, it is important to note that the smallest increases in blood lead levels were observed in communities with mines or inactive smelters. This observation has been explained by studies demonstrating reduced absorption of lead from these soils.

Response: This information has been added to the public health assessment.

Comment: Page 33, Recommendation No 2 regarding determination of the total extent of groundwater contamination. This recommendation is not relevant.

Response: Based upon the data submitted by another commentator, ATSDR agrees that the groundwater monitoring recommendation is not necessary. The public health assessment has been revised accordingly.

Comment: Page 33, Recommendation No. 3. Air emissions from the residual piles are being controlled as indicated by the ongoing ambient air monitoring program under the oversight of EPA Region VI. This recommendation is not relevant.

Response: Based upon the data submitted by another commentator, ATSDR agrees. This recommendation has been revised to state that the control of air emissions from the residual piles should continue.

FOOTNOTES

1. The National Toxicology Program in its Annual Report on Carcinogens classifies a chemical as a "known human carcinogen" based on sufficient human data. Its classification of a chemical as being "reasonably anticipated to be a carcinogen" is based on limited human or sufficient animal data.

2. IARC defines a class 1 carcinogen as a substance which studies in humans indicate a causal relationship between the agent and human cancer. Class 2 carcinogens are those reasonably anticipated to be carcinogens. For a 2A classification, there is limited evidence of carcinogenicity from human studies

which indicate that a causal interpretation is credible, but not conclusive. A classification of 2B indicates that there is sufficient evidence of carcinogenicity from studies in experimental animals.

3. In EPA's classification scheme, a chemical is considered a class A or human carcinogen based on sufficient evidence from studies of humans. A substance is considered class B1 if there is limited evidence from human studies. B2 is used when evidence for carcinogenicity is inadequate or non-existent based on human studies, but sufficient based on animal studies.

4. Category I: The substance meets the definition of a potential occupational carcinogen in (i) humans, or (ii) in a single mammalian species.
Category II: The substance (i) meets the definition of a potential occupational carcinogen but the evidence is suggestive.

5. The Maternal and Child Health Service, Oklahoma State Department of Health (OSDH), conducted the blood lead testing in collaboration with the OSDH environmental unit. The OSDH environmental unit became a part of the Oklahoma Department of Environmental Quality in 1993. The unit continues to oversee this work.

6. Personal communication with Monty Elder, Oklahoma Department of Environmental Quality.

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Agency for Toxic Substances and Disease Registry, 1825 Century Blvd, Atlanta, GA 30345
Contact CDC: 800-232-4636 / TTY: 888-232-6348