Sampling and Metal Analysis of Chat Piles in The Tar Creek Superfund Site

Tar Creek Superfund Site

Ottawa County, Oklahoma

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By

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ABSTRACT

The Tar Creek Superfund Site encompasses 40 square miles in far northeastern Oklahoma and affects the towns of Quapaw, Commerce, Picher, North Miami, and Cardin and more recently Miami. The site is part of the former Tri-state Mining Area that extended from northeastern Oklahoma, through southeast Kansas, and into southwest Missouri. Extensive lead and zinc mining during the early 1900's through the 1960's resulted in the formation of acid mine water that has contaminated the shallow ground water and surface water with iron, sulfate, zinc, lead, and cadmium at the Tar Creek site. Additionally, large volumes of mine tailings (chat) left over from the milling operations are still present on the surface at the site.

This chat is comprised of mostly angular chert fragments of less than ¼ inch and contains residual amounts of lead and zinc. Chat has been used for many purposes including aggregate for asphalt used in roads, as gravel for driveways and county roads, and as fill material in many residential and commercial buildings and yards.

Part of the goal of the nonresidential Remedial Investigation/Feasibility Study (RI/FS) for the Tar Creek Superfund Site will be to characterize the metal (lead, cadmium, and zinc) content (concentrations and spatial distribution) of the chat piles in the area. The results of this sampling effort will be used to develop a sampling strategy to characterize the huge volume of chat.

The Land Protection Division of the Oklahoma Department of Environmental Quality (DEQ) sampled several mining waste (chat) piles. These piles are located in the area of Cardin and Picher, Oklahoma within the Tar Creek Superfund Area. The purpose of sampling was to provide information concerning the variation of metals content and particle size within a chat pile. Chemical analyses of the raw chat provide data on the concentrations of metals at each sample location. Chemical analyses of sieved chat sample were conducted to determine the distribution of metals concentrations with particle size.

Some conclusions from this study were that: (1) chat piles contain high concentrations of metals (Pb, Cd, Zn) especially in the finer sized material, relative to background soils and lead relative to human health risk levels, (2) the #40 sieve (0.425 mm) represents a break point where the concentrations of lead begin to rise greatly for those particles that pass this sieve size, (3) the amount of material < 0.425 mm represents only about 20% of the total chat volume but contains at least one half up to 80% the lead mass while the bulk of the chat is of larger particle size and displays very low metal concentrations, (4) average metal content of a chat pile may be characterized with as few as 10 samples independently of volume or area but this does not translate to determining a safe use of the chat, (5) there is larger variation of metal concentrations between different chat piles and less variably within a single chat pile but the particle distribution (well graded) is fairly consistent throughout, (6) a good correlation has been demonstrated between the inductively coupled plasma (ICP) method and laboratory X-ray Fluorescence (XRF) method of analyses for chat samples, and (7) chat sampling protocol (sieving) needs to be established to compare metals concentrations to risk based levels.

LIST OF ACRONYMS

AGI	American Geological Institute
ATRC	Atlas Raw Chat
ATWSC	Atlas Wet Sieving Coarse
ATWSSF	Atlas Wet Sieving Screwfines
ATT2SS	Atlas Type 2 Slurry Seal Fines
ATT2SSC	Atlas Type 2 Slurry Seal Coarse
ATPWI	Atlas Process Water Inflow
ATPWO	Atlas Process Water Outflow
ATPWO-3	Atlas Filtered Sample
BLM	Bureau of Land Management
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980 also known as Superfund: Amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA)
CFR	Code of Federal Regulations
CY	Cubic Yard – Volume Measurement Unit
DEQ	Oklahoma Department of Environmental Quality
DI	Deionized Water
EPA	United States Environmental Protection Agency
EPAHL	United States Environmental Protection Agency Houston Laboratory
HHA	High Access Areas
ICP	Inductively coupled plasma method
KNRC	Kenoyer North Raw Chat Pile
KNMRRFA	Kenoyer North Mixed River Rock with Fly Ash
KNMCLAY	Kenoyer North Mixed Clay
KNFA	Kenoyer North Fly Ash
KN2RC	Kenoyer North Pile Number 2, which is the Kenoyer South Raw Chat Pile
MAX	Maximum
MIN	Minimum
µg/dL	microgram per deciliter
mg/kg	Milligram per Kilogram
NPL	National Priorities List: A list of sites identified for remediation under CERCLA
OSDH	Oklahoma State Department of Health
OSWER	Office of Solid Waste and Emergency Response
OTWSC	Ottawa Wet Sieving Coarse
OTRC	Ottawa Raw Chat
OTWSSSF	Ottawa Wet Sieve Sand Screwfines
OTT2SS	Ottawa Type 2 Slurry Seals (Harp Screens at 6 mm)
OTT2SSC	Ottawa Type 2 Slurry Seal COARSE (Harp screen #5)
OTWSSED	Ottawa Wet Sieving Sediment
OTPWI	Ottawa Process Water Inflow
OTPWO	Ottawa Process Water Outflow
OTPWO-2	Ottawa Filtered Sample
OTMUW	Ottawa Make-Up Water
OU	Operable Unit
PRP	Potentially Responsible Party

LIST OF ACRONYMS CONTINUED

QA	Quality Assurance
QC	Quality Control
RCRA	Resource Conservation and Recovery Act
RD	Remedial Design
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
SEL	Oklahoma State Environmental Laboratory
STD DEV	Standard Deviation
TCLP	Toxicity Characteristic Leaching Procedures
USACE	United States Army Corps of Engineers
XRF	X-ray Fluorescence Method

Sampling and Metal Analysis of Chat Piles located in The Tar Creek Superfund Site

Introduction

Part of the goal of the nonresidential Remedial Investigation / Feasibility Study (RI/FS) for the Tar Creek Superfund Site will be to characterize the total metal (lead, cadmium, and zinc) content (concentrations and spatial distribution) within the chat piles in the area. This is needed to help determine appropriate uses of this chat. There are large volumes of chat located in this area, approximately 50 million cubic yards. The chat has a density of 107 lbs/ft^3 (Dames and Moore, 1993), which equates to approximately 72 million tons of chat still left in the area. The results of this study should help determine the number and type of samples needed to characterize a chat pile considering the lead, cadmium, and zinc content and particle size distribution.

The Land Protection Division of the Oklahoma Department of Environmental Quality (DEQ) sampled two mining waste (chat) piles. These piles are located in Cardin, Oklahoma within the Tar Creek Superfund Area as presented in Figure 1. The purpose of sampling was to provide information concerning the distribution of metals concentrations and particle size within a chat pile. Chemical analyses of the raw chat provide data on the concentrations of lead, cadmium, and zinc at each sample location. Several county roads that contain chat were sampled to get an idea of the concentrations of lead, cadmium, and zinc in the roads. Also, different mixtures of chat, river rock, clay, and fly ash were sampled and analyzed to provide additional data for alternative road building materials. Sieve analyses were performed on several raw chat samples. Chemical analyses by the inductively coupled plasma (ICP) method of each sieve size fraction were conducted to determine the distribution of lead, cadmium, and zinc concentrations with particle size. A comparison of chemical analyses from three different laboratories was also planned. This included the Oklahoma State Environmental Laboratory (SEL), the EPA Houston Laboratory (EPAHL), and a private laboratory. Since the time that the data were analyzed, the private laboratory was accused of falsifying data. Therefore, the data from the private laboratory will not be presented.

Background

The Tar Creek site encompasses 40 square miles in far northeastern Oklahoma and affects the towns of Quapaw, Commerce, Picher, North Miami, and Cardin (see Figure 1). The site is part of the former Tri-state Mining Area that extended from northeastern Oklahoma, through southeast Kansas, and into southwest Missouri. Extensive lead and zinc mining during the early 1900's through the 1960's resulted in the formation of acid mine water that has contaminated the shallow ground water and surface water with iron, sulfate, zinc, lead, and cadmium at the Tar Creek site.

Mine tailings (chat) are comprised of mostly angular chert fragments and contain residual amounts of lead. According to American Geology Institute (AGI) (Gary, McAfee, and Wolf, 1977) "Glossary of Geology", chert is a hard, extremely dense or compact, dull to semi-vitreous, cryptocrystalline sedimentary rock, consisting dominantly of cryptocrystalline silica (chiefly fibrous chalcedony). Chat is the waste product (tailings) derived from milling operations

(jigging) to recover lead and zinc and consists of material typically ranging in diameter from 5/8 inch to less than 0.003 inches or 75 micro meters [μm] (No. 200 sieve). The milling operations conducted by Eagle Picher Company are described in an article in the *Engineering and Mining Journal* entitled "Central Mill" by Elmer Isern (Isern, 1943). The general flow of the ores was stated as follows: "The ores from the mines are hauled to the mill by standard-gage railroad equipment or by trucks. The ores from each mine are hauled separately and are weighed and sampled separately, after which they lose their individual identity and are mixed together in a common storage hopper. In general, the treatment of the ores is divided into three phases:

1. The ores are crushed to minus 1½ in. The Heavy Media separation process treats the size minus 1½ in. plus 3/16 in. where a tailing is discarded and a crude concentrate made. This crude concentrate is ground to flotation size and floated.
2. The minus 3/16 in. plus #35-mesh product is treated over jigs, where a tailing is discarded and a concentrate is made, which is ground to flotation size and floated.
3. The minus #35 mesh product is treated over flotation machines along with the concentrates from the Heavy Media Separation process and jig plant. Here a final tailing is discarded and lead and zinc concentrates are made for shipment."

Chat has been used for many purposes including aggregate for asphalt in roads and as gravel for driveways and county roads. The use of chat in driveways and as fill material has contributed to lead contamination of soils in residential property and has contributed to elevated blood lead concentrations in area children. The Environmental Protection Agency (EPA) is now conducting soil remediation work in the cities of this area.

The purpose of this study is to determine the methodology and number of samples necessary to properly characterize a chat pile. Another purpose of this sampling is to determine the variability of lead, cadmium, and zinc concentrations within a chat pile. This will determine appropriate management of chat prior to or during its use.

Chat is used as a pile run material (raw chat), as washed (wet sieved), and as screened (dry sieved) material for aggregate in asphalt mixes for roads. The fine particles from the dry screening are used as an aggregate for slurry seal asphalt mixtures for road maintenance and repairs. The coarse material from the dry screening and raw chat are both used as source material in the wet screening (washing) operation. DEQ has prepared a report on the results of sampling washed chat (DEQ, 2000).

The Environmental Protection Agency (EPA) is leading the ongoing cleanup of residential properties. The soil action level for lead is 500 mg/kg (EPA, 1997a). About 1,647 properties have been cleaned as of April 2002. There are approximately 457 residential properties in the five mining towns remain to be remediated. Starting in February 2002, EPA extended sampling of high access areas (HHA) such as daycare centers, schools, parks in Miami, Oklahoma and surrounding areas. To control the chat usage in areas where children may be located, the DEQ established a guideline, effective June 1, 2000, that restricts the use of chat in residential areas (see Appendix A for the guideline).

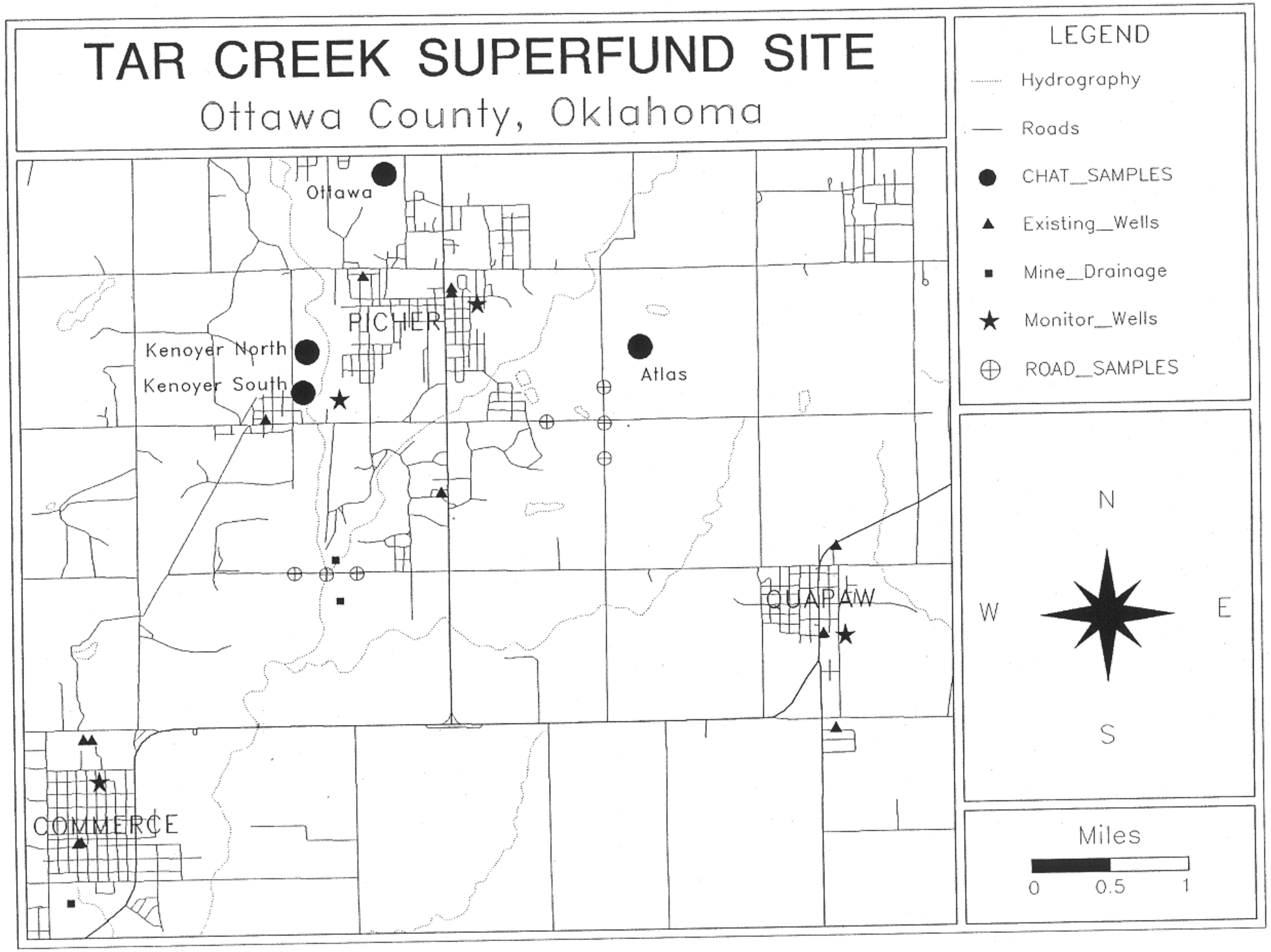


Figure 1. Tar Creek Superfund Site Sampling Locations

Summary of Sampling

This report will summarize sampling protocol, present results from this and other sampling events, discuss the results, discuss the risk implications, make conclusions and possible recommendations related to further data needs. The data in this report includes results from this project as well as data from previous sampling events in Oklahoma, Kansas, and Missouri. Samples from graveled county roads and mixtures of chat with some other types of material were also collected. Personnel from DEQ collected samples from the Kenoyer Chat piles on July 19, 2000 and county road samples were collected on September 6, 2000.

The DEQ obtained samples of chat from several chat piles for chemical analyses for lead, cadmium, and zinc concentrations and particle gradation analyses. The samples were collected from a traverse across the face of a chat pile. This provides information about lead, cadmium, and zinc concentrations, variation and particle size distribution within a chat pile. The State Environmental Laboratory (SEL) and the EPA Region 6 Environmental Service Branch Laboratory located in Houston, Texas (EPAHL) performed chemical analyses of each size fraction for lead, cadmium, and zinc. Samples for particle sizing were obtained from raw chat in two different chat piles located on the Kenoyer site and one sample each on chat composites from chat piles located at the Ottawa and Atlas sites. The chat particles were separated into six size fractions using the following sieves: the 3/8 inch, #4, #10, #40, #80, and #200 screen sizes plus the material passing the #200 screen (material collected on the pan). The material was collected from each of the sieves and the pan for analysis of metal concentrations. An independent geotechnical laboratory, Standard Testing in Oklahoma City performed the sieve sizing. It should be noted that the sieves were not decontaminated with deionized (DI) water between sieve analyses. Instead they were shaken clean by hand and brushed to remove any particles stuck in the mesh.

The samples were dried and then a representative portion selected for analysis and weighed by SEL personnel. The chat samples were not crushed or ground prior to analysis. All QA / QC testing was performed prior to issuing analytical reports. The concentration results are reported in units of mg/kg on a dry weight basis.

The south face of the Kenoyer North Chat Pile (KNRC) located between Picher and Cardin, Oklahoma was sampled. This chat pile has been used over time such that the south face was open, i.e. exposed. Samples were collected from a traverse across this face such that the outer surface and the interior of the pile were sampled. The total length of 561 feet was divided into eleven segments approximately 51 feet in width. The volume of this pile as of May 1999 (USACE, 1999) was approximately 1,201,221 cubic yards. The following is a description of the sampling technique:

- A front-end loader was used to take one bucket of chat from each of the eleven (11) locations within the open face at the designated pile. The locations selected were representative of the open side of the pile. The samples were taken from a height equal to that of the front-end loader. Each scoop was divided into fourths and a 5-part composite sample taken from each of the four sections. Each composite sample filled a one gallon zip-lock plastic bag. This resulted in a total of 44 samples. Duplicates were taken for every 10 samples, which resulted in five duplicate samples. At the first and sixth sample locations, an additional four gallons

of composite sample was collected at each site for sieve analyses. These locations were chosen because the first location was closer to the outer surface and the sixth location was closer to the center and interior of the pile. The gradation analysis of the raw chat was divided into six size fractions using the following sieves: the 3/8 inch, #4, #10, #40, #80, and #200 screen sizes plus the material passing the #200 screen (material collected on the pan). Two duplicate samples were collected from the #80 sieve for QA conformance. The State Environmental Laboratory (SEL), EPA Houston Laboratory, and a private laboratory analyzed each size fraction of these sieved samples for total metals (Pb, Cd, and Zn) using the inductively coupled plasma (ICP) method.

- Each composite sample was analyzed for Pb, Cd, and Zn. The SEL analyzed all samples using the X-ray Fluorescence (XRF) method, using a laboratory XRF and every tenth XRF sample was also analyzed using the inductively coupled plasma (ICP) method.

The west face of the Kenoyer South Chat Pile (KN2RC), located in Cardin just south of the chat pile described above, was sampled at three locations. This chat pile has an open face similar to the Kenoyer North Chat Pile only smaller in size. The sampling technique was similar to that used at the Kenoyer North Pile and is described as follows:

- A front-end loader was used to take one bucket of chat from three locations across the face from south to north. The locations selected were representative of the open side of the pile, one at both ends and one in the middle. The samples were taken from a height equal to that of the front-end loader. Each scoop was divided into fourths and a 5-part composite sample was taken from each of the four sections. Each composite sample filled a one gallon zip-lock plastic bag. This resulted in a total of 12 samples.

- An additional composite sample was collected at every 10 samples for QA purposes. This resulted in 2 additional samples.

- Each composite sample was analyzed for Pb, Cd, and Zn. The SEL analyzed these samples using the XRF and every tenth XRF sample using the ICP.

Statistical Design

Analyses of samples were by XRF. An excellent correlation between ICP and XRF analytical results was reported in another study of the contaminated residential soils at the Tar Creek Superfund Site in Oklahoma (Ecology and Environment, 1996a). The application of the correlated data for soils may be limited if extended to chat analysis. This is why in this study every tenth sample was analyzed on the ICP. The scatter plots from this study by Ecology & Environment (Ecology and Environment, 1996a) are shown in Figures 2, 3, and 4, respectively.

This sampling program was designed to provide a spatial summary of the conditions that exist within the chat pile. Additionally, the sieved samples were used to help identify any correlation between particle size distribution and lead, cadmium, and zinc concentrations. The maximum particle size associated with contaminants exceeding different remedial action levels was also identified. This sampling program was developed to aid in characterizing chat for potential end

uses in non-residential areas such as roads and to define sampling and analysis protocols for chat usage.

The required number of samples to characterize a chat pile was calculated to be 221 (Brown and Root, 1995) using chat data from the Cherokee County, Kansas, and Jasper County, Missouri Remedial Investigations (RI) (Dames and Moore, 1993 and Dames and Moore, 1995). Due to economic constraints and the fact that the sampling will be used to define an average value of lead, cadmium, and zinc concentrations for the chat pile and not to identify the general concentration variability, the number of samples required by Brown & Root (Brown and Root, 1995) was modified as follows. The five part composite samples were considered an average of five separate grab samples. This reduced the number of samples for analysis from 221 to 44 or ($221 \div 5 = 44.2$). This should provide an adequate cross section of the chat pile under investigation to obtain a reliable average concentration for the chat. The equation (EPA, 1992) for calculating the required number of samples necessary to define a population mean is given in Appendix B.

Results

XRF versus ICP

A correlation between XRF and ICP was examined to include the sampling of chat. Figures 5, 6, and 7 show the correlation between ICP and XRF for the samples taken at the Kenoyer North Chat Pile and the Kenoyer South Chat Pile that were analyzed by the SEL for lead, cadmium, and zinc, respectively. A good correlation for lead ($R^2 = 0.94$) is indicated and the slope is similar ($m = 1.0625$) to that observed in the E&E study (1996) for lead, ($R^2 = 0.909$ and $m = 0.912$). The results for zinc ($R^2 = 0.892$ and $m = 0.891$) are similar to lead but the cadmium ($R^2 = 0.678$ and $m = 0.437$) is lower. The values for zinc ($R^2 = 0.924$ and $m = 0.979$) and cadmium ($R^2 = 0.860$ and $m = 0.979$) from the Ecology & Environment study (Ecology and Environment, 1996a) give a better correlation. The negative values on Figure 6 result from plotting the log of very small cadmium concentrations. This analysis shows XRF is acceptable for chat analysis.

Total lead, cadmium, and zinc concentrations of raw chat

The lead, cadmium, and zinc concentrations for each composite sample of raw chat analyzed by XRF are shown in Tables 1 and 2 of Appendix C for the Kenoyer North and South Chat Piles, respectively.

The summary statistics for the concentrations of lead, cadmium and zinc associated with the raw chat in four piles studied in Oklahoma are shown in Table 1. The chat pile identification, number of samples, mean, standard deviation, maximum concentrations and minimum concentrations reported in mg/kg are indicated in the Table 1 and discussed in the following paragraphs.

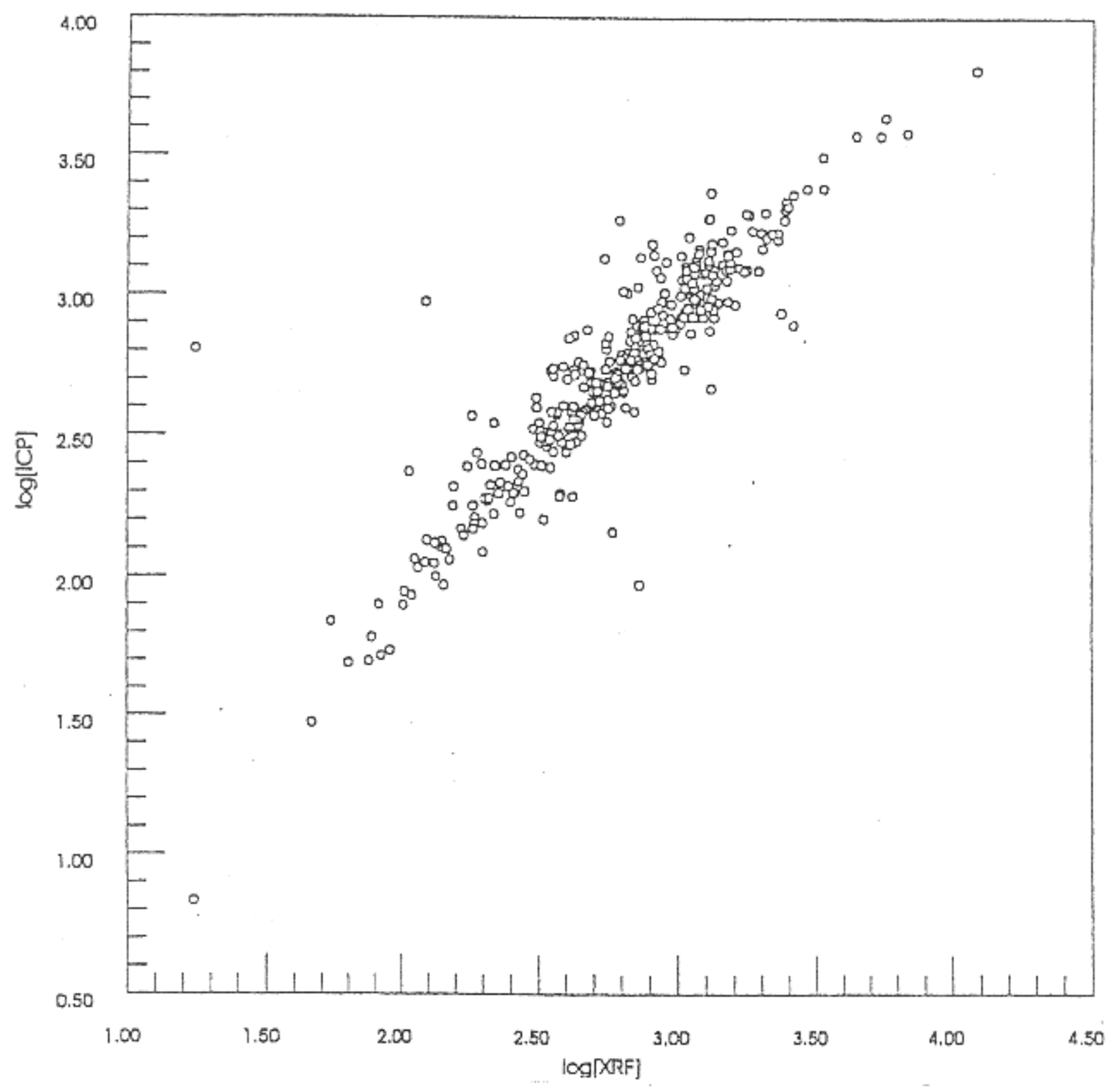


Figure 2. Scatterplot of log [ICP] versus log [XRF] for lead (Ecology & Environment 1996a)

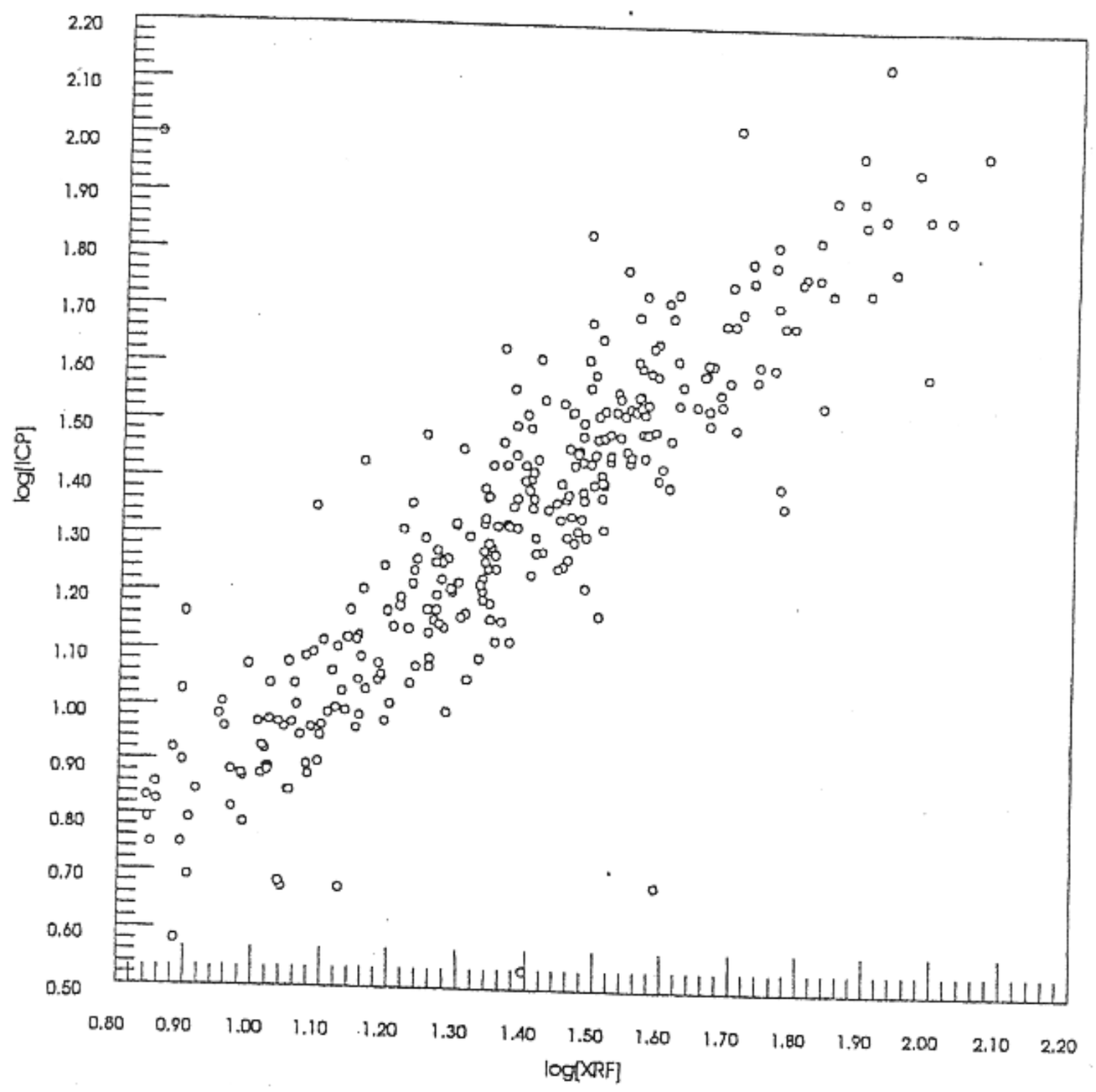


Figure 3. Scatterplot of log [ICP] versus log [XRF] for cadmium (Ecology & Environment 1996a)

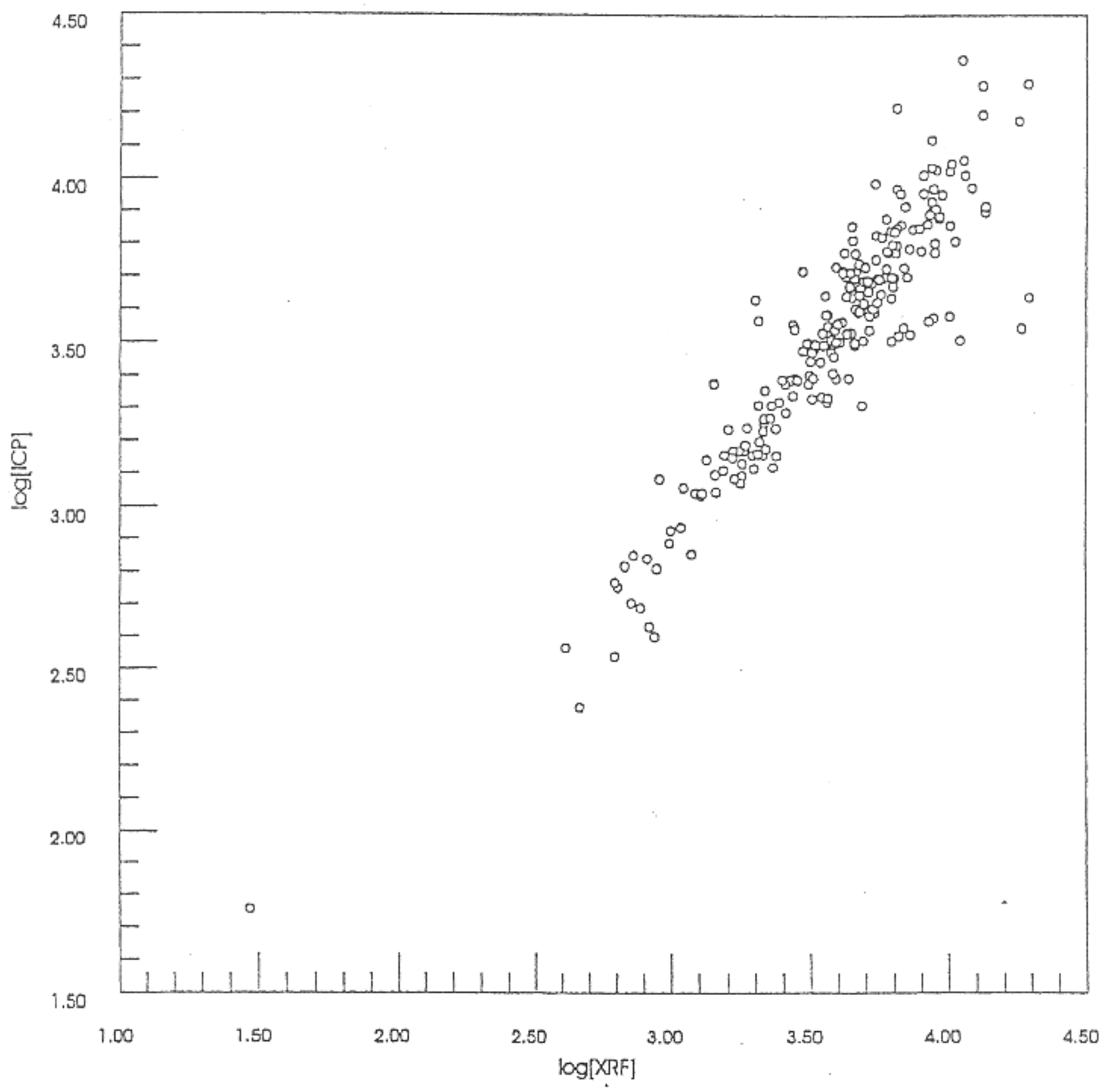


Figure 4. Scatterplot of log [ICP] versus log [XRF] for zinc (Ecology & Environment 1996a)

Figure 5. Scatterplot of log[ICP] versus log[XRF] for Lead from the Kenoyer Chat Pile
Tar Creek Superfund Site
Ottawa County, Oklahoma

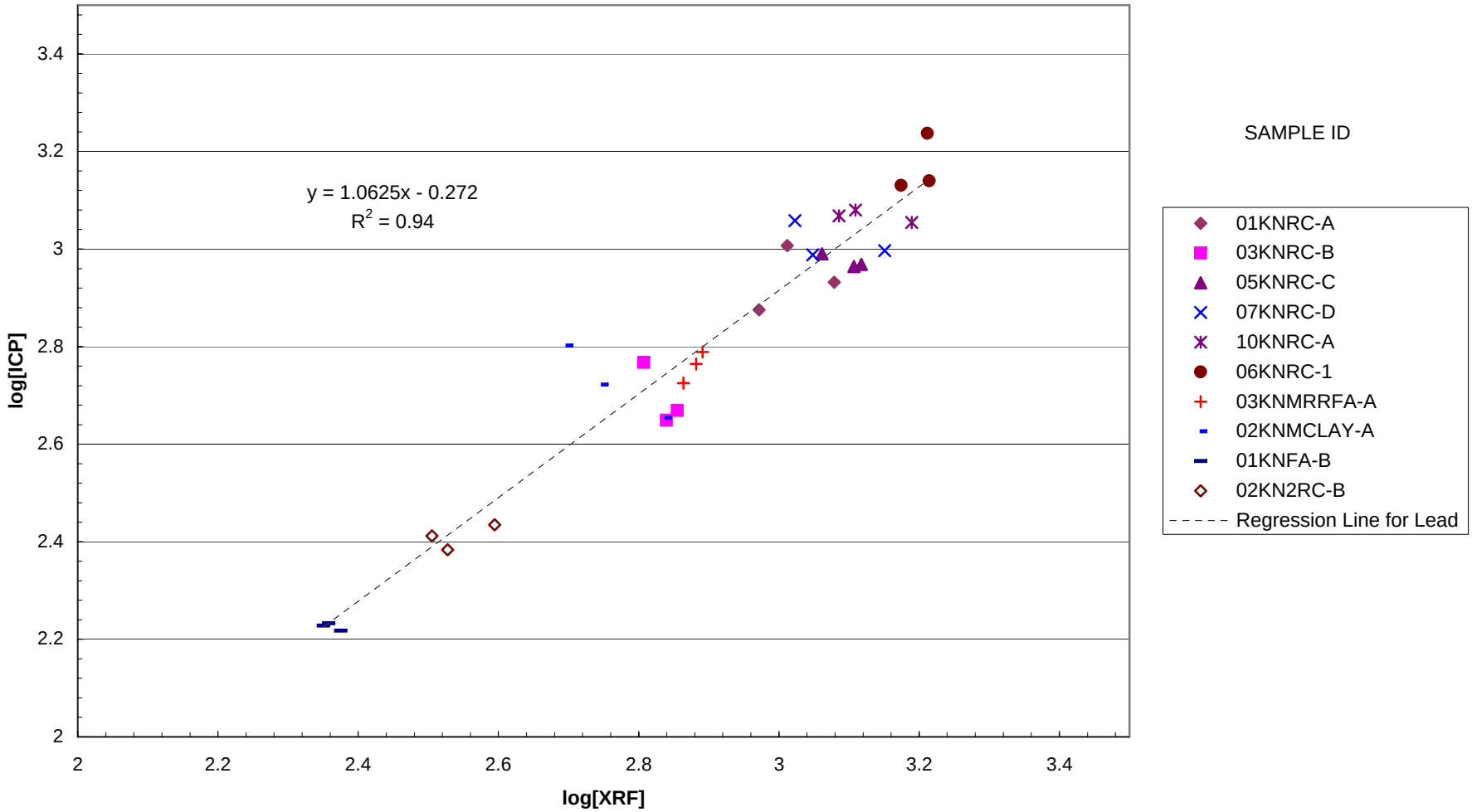


Figure 6. Scatterplot of log[ICP] versus log[XRF] for Cadmium from the Kenoyer Chat Piles
Tar Creek Superfund Site
Ottawa County, Oklahoma

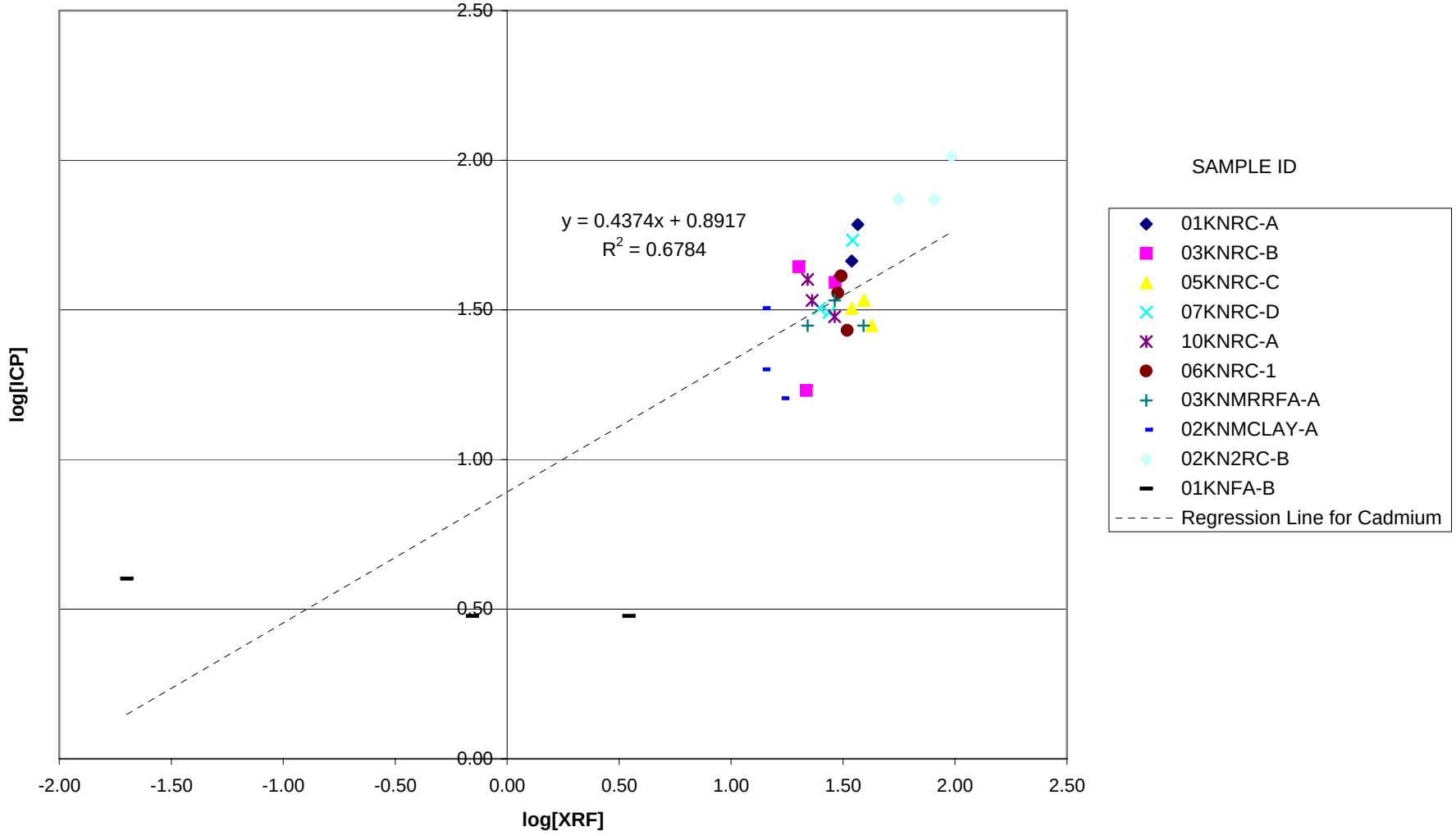


Figure 7. Scatterplot of log[ICP] versu log[XRF] for Zinc from the Kenoyer Chat Piles
Tar Creek Superfund Site
Ottawa County, Oklahoma

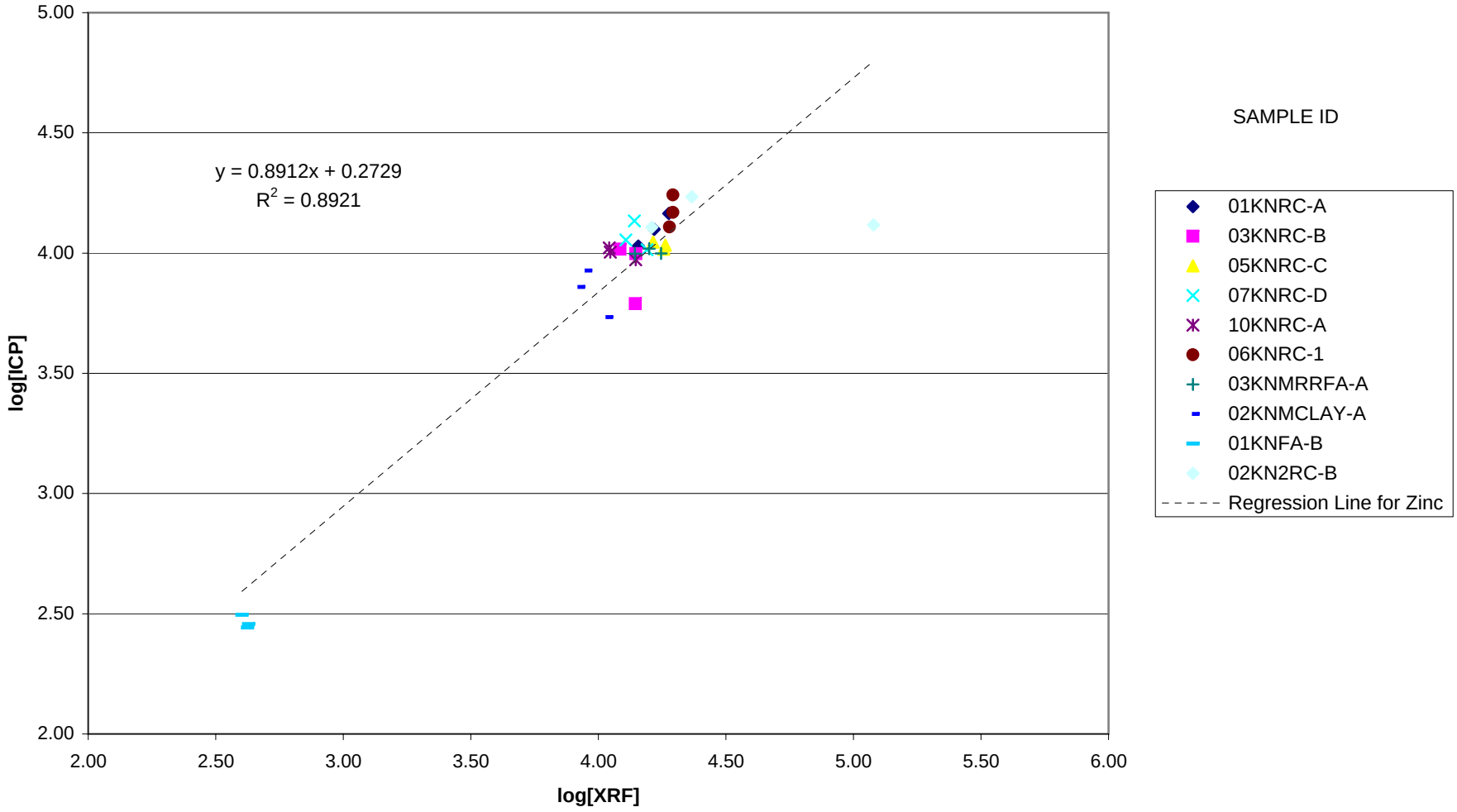


TABLE 1. STATISTICS FOR LEAD, CADMIUM, AND ZINC (mg/kg) IN CHAT PILES LOCATED IN THE TAR CREEK SUPERFUND AREA.

CHEM	LOCATION	NO. Of SAMPLES	MEAN (mg/kg)	STD DEV	MIN (mg/kg)	MAX (mg/kg)
Lead	Kenoyer North	49	1,314	389	631	2,207
	Kenoyer South	14	352	95	258	563
	Atlas	2	314			
	Ottawa	1	732			
Cadmium	Kenoyer North	49	33	13	16	71
	Kenoyer South	14	63	21	32	96
	Atlas	2	44			
	Ottawa	1	57			
Zinc	Kenoyer North	49	16,895	4,475	11,138	34,407
	Kenoyer South	14	17,115	2,608	13,898	23,247
	Atlas	2	8,876			
	Ottawa	1	11,086			

The analytical results for the Kenoyer North Chat Pile are shown on Figures 8, 9, and 10 for lead, cadmium, and zinc. The locations are from west to east across the chat pile face on the south side.

The analytical results for the Kenoyer South Chat Pile are shown on Figures 11, 12, and 13 for lead, cadmium, and zinc, respectively. The locations are from south to north across the west face of the chat pile.

One chemical analysis of raw chat was performed on a composite sample from the Ottawa pile and two were performed on a composite sample of the Atlas chat. All samples were analyzed by the SEL using ICP method and the results are reported on a dry weight basis. The chat was not crushed or ground prior to analyses.

The Kenoyer North has the highest average lead concentration (1,314 mg/kg) while the Atlas has the lowest lead (314 mg/kg) concentrations. The Kenoyer South has an average lead concentration similar to the Atlas (352 mg/kg) but has the highest average zinc concentration (17,115 mg/kg) and the highest average cadmium concentration (63.3 mg/kg). The Ottawa has intermediate concentrations of lead (732 mg/kg), cadmium (57 mg/kg), and zinc (11,086 mg/kg) although only one composite sample of chat was analyzed.

Discussion

Data was compared from these sampling and previous sampling events in Oklahoma, Kansas, and Missouri. Table 2 shows the averages for lead of other chat piles located in Oklahoma, Kansas, and Missouri. This data came from information compiled in the document *Sampling and Analysis Plan* (Brown and Root, 1995) and the Bureau of Land Management report entitled *Final Additional Site Characterization Report for the Tar Creek NPL Site* (Johnson and Malthotra, 1999). Additional information can be found in the *Final Remedial Investigation for Cherokee County, Kansas* (Dames and Moore, 1993) and the *Final Remedial Investigation*

Figure 8. Total Lead Concentrations at The Kenoyer North Chat Pile
Tar Creek Superfund Site
Ottawa County, Oklahoma

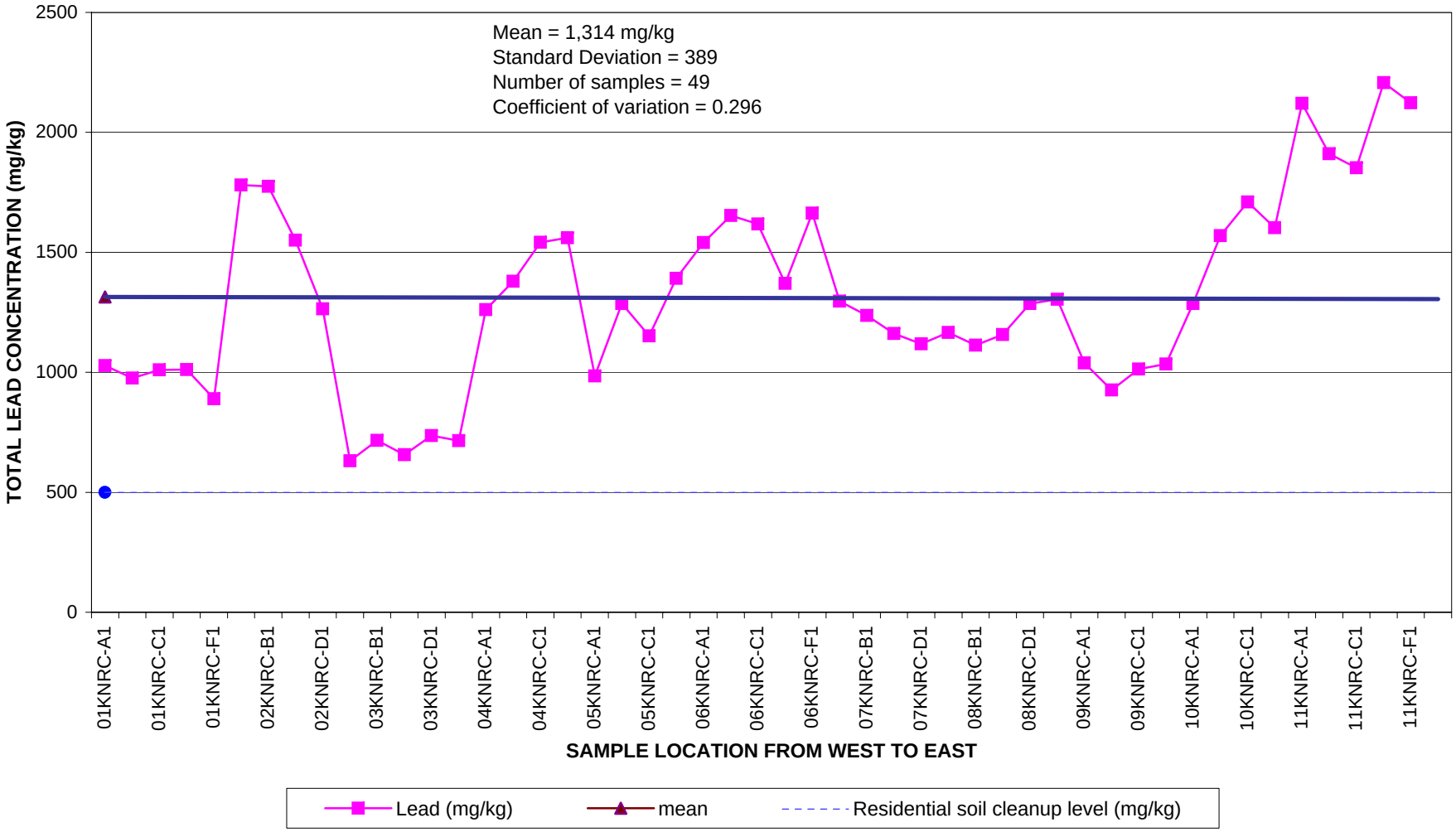


Figure 9. Total Cadmium Concentrations at The Kenoyer North Chat Pile
Tar Creek Superfund Site
Ottawa County, Oklahoma

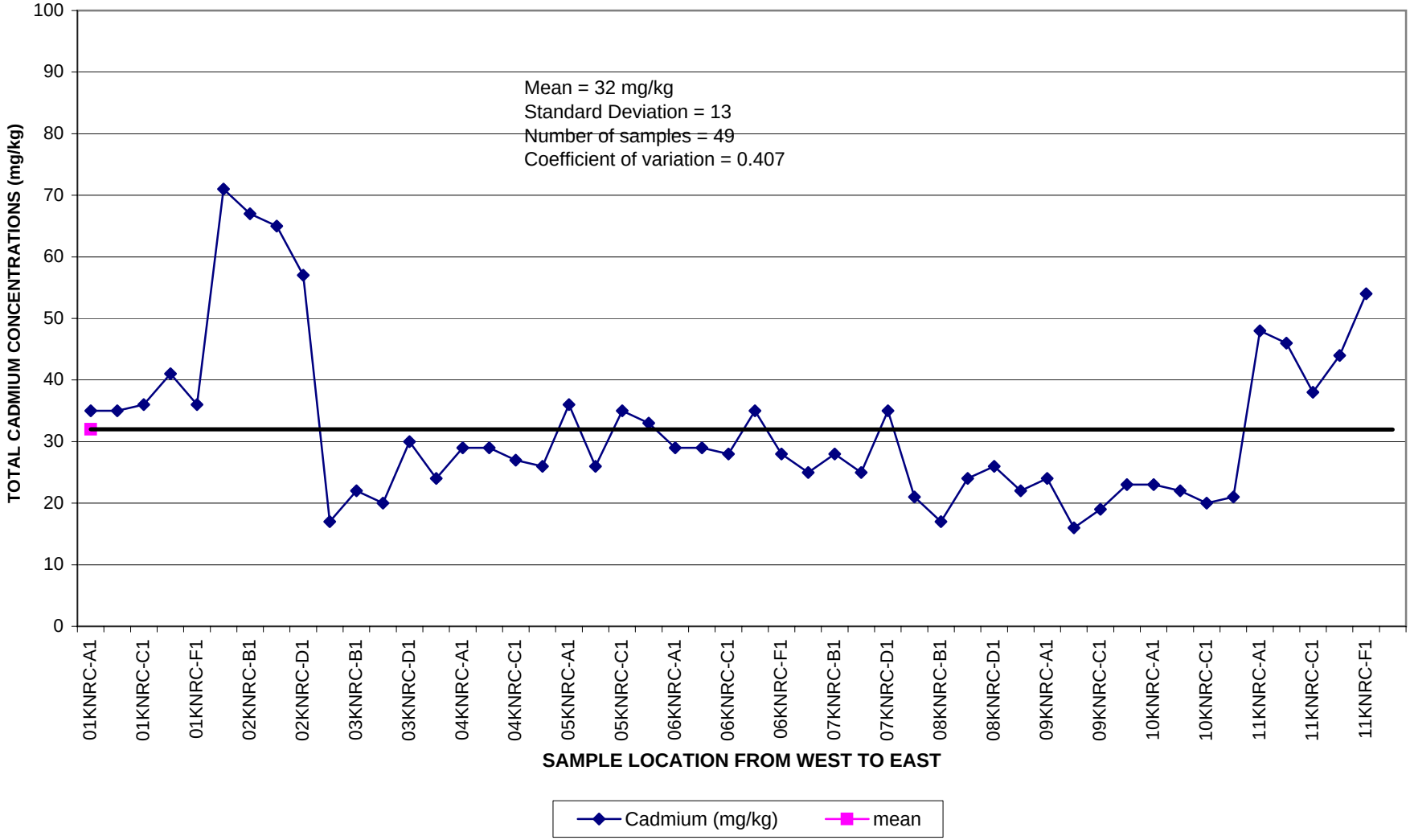


Figure 10. Total Zinc Concentrations at The Kenoyer North Chat Pile
Tar Creek Superfund Site
Ottawa County, Oklahoma

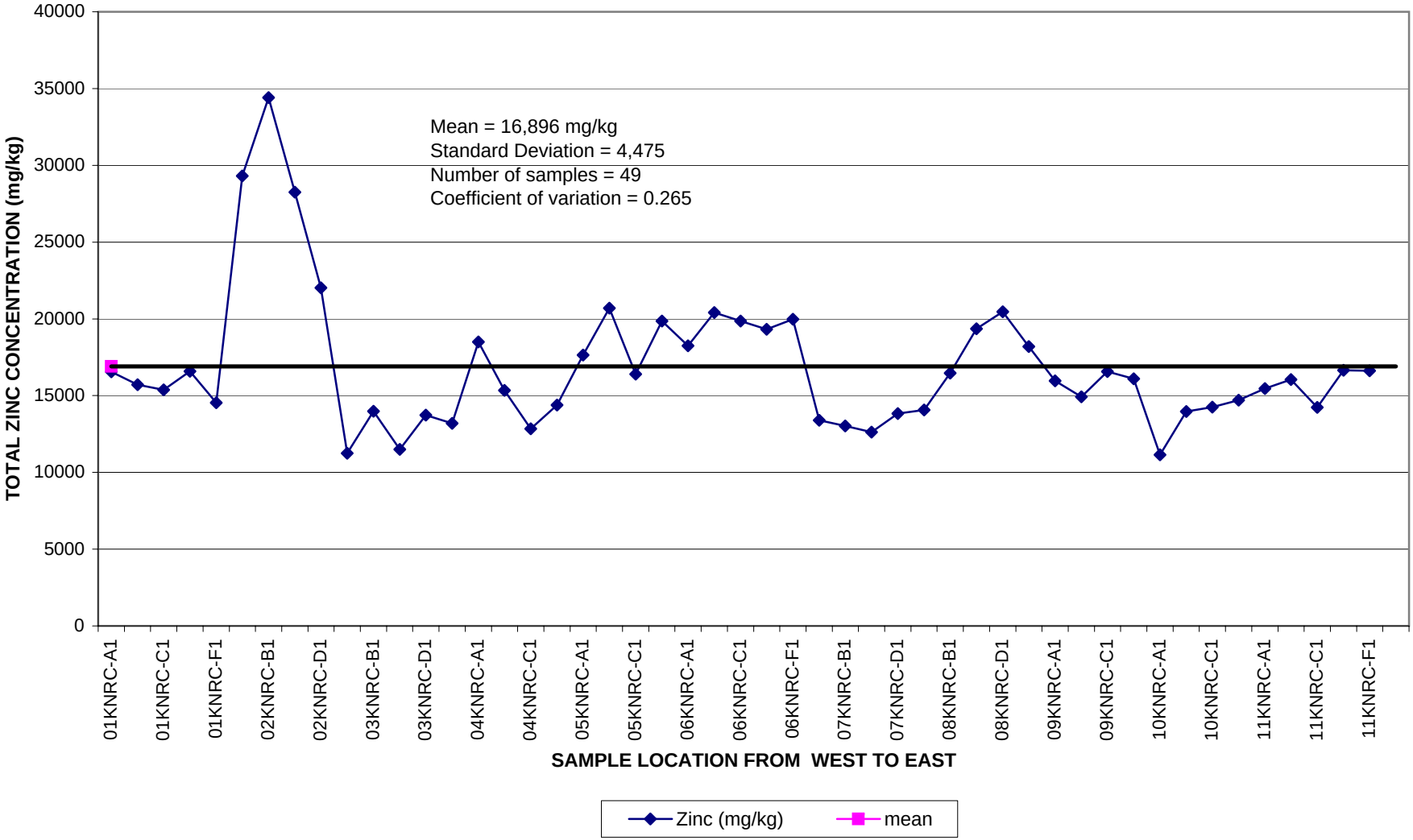


Figure 11. Total Lead Concentrations at The Kenoyer South Chat Pile
Tar Creek Superfund Site
Ottawa County, Oklahoma

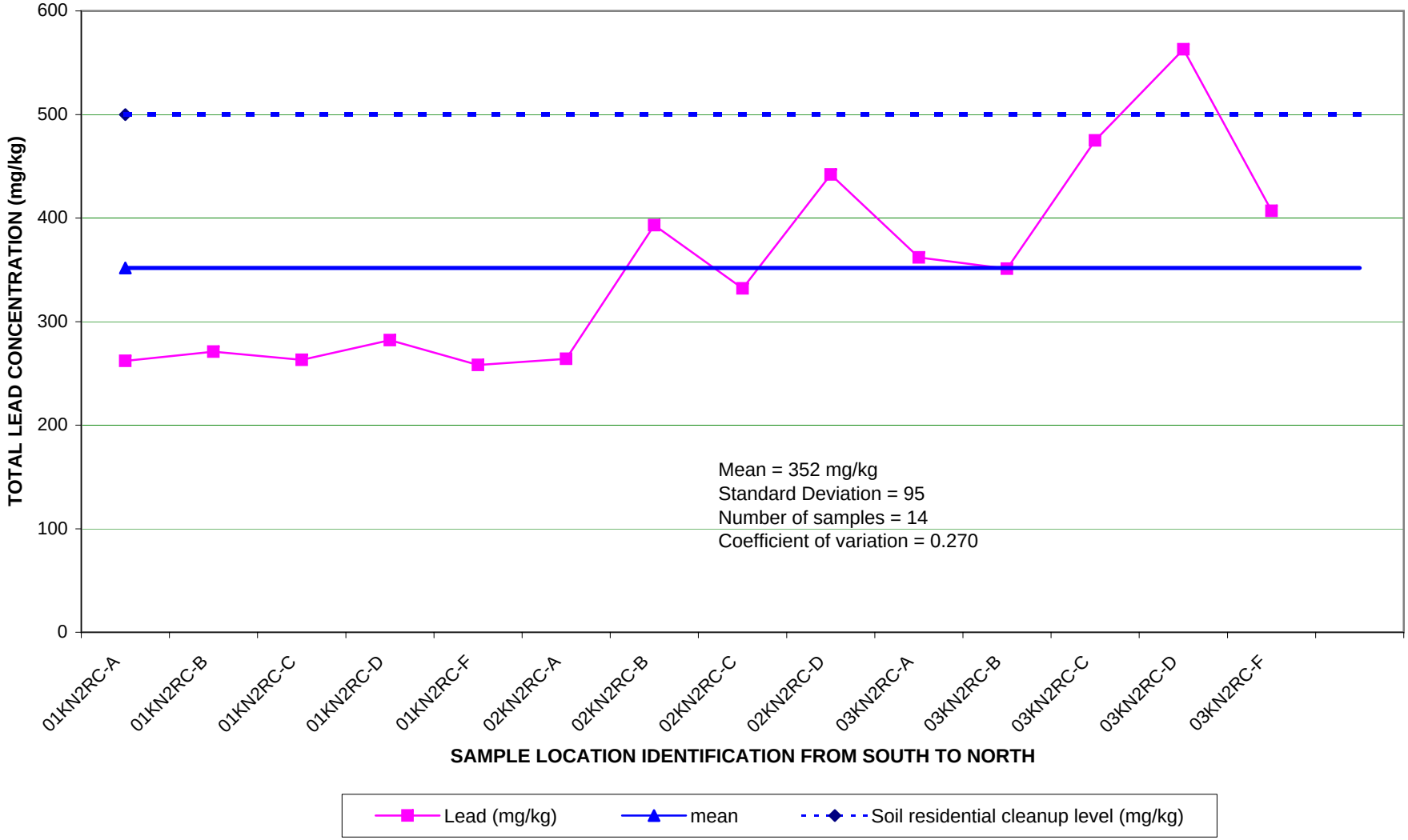
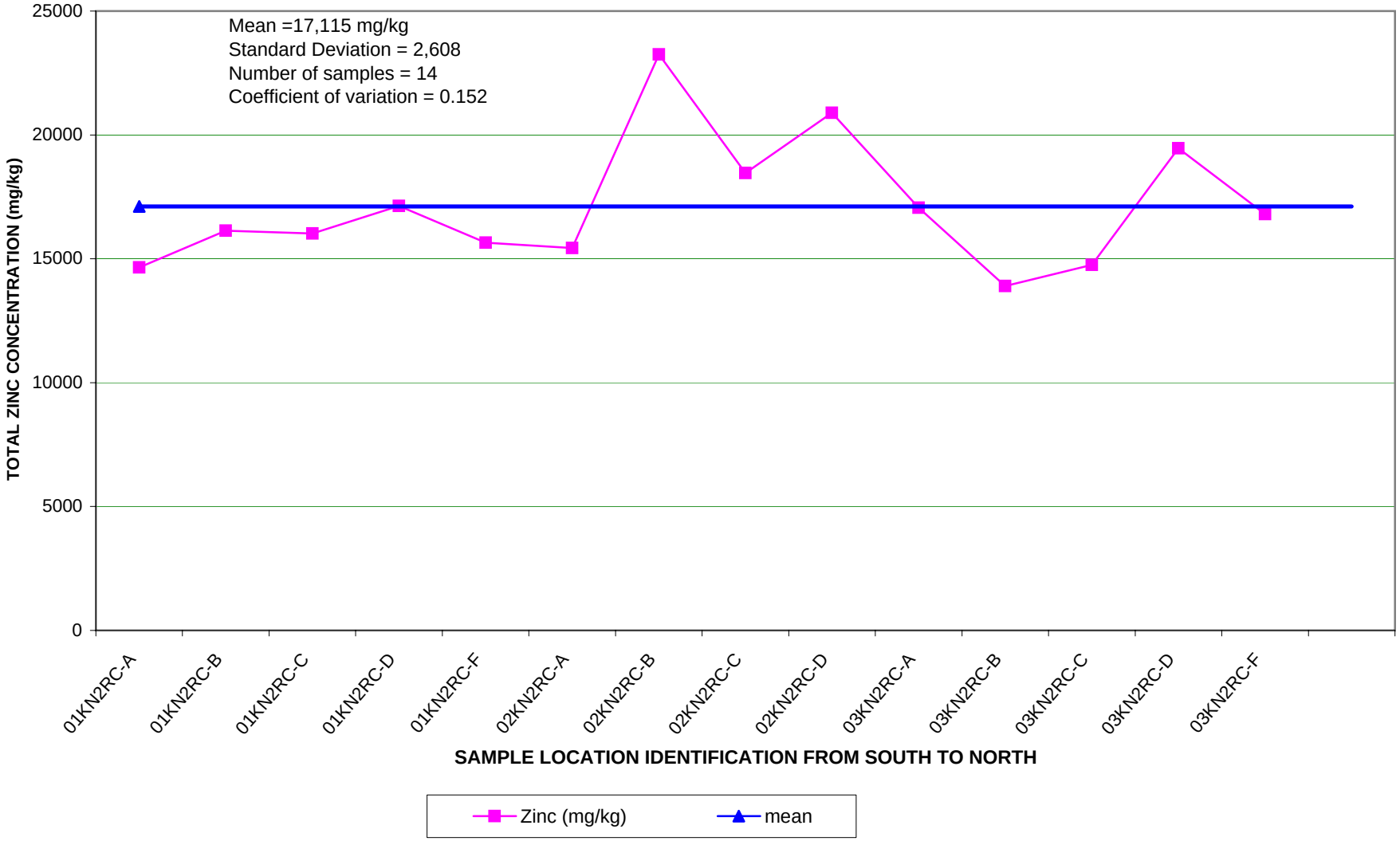


Figure 12. Total Cadmium Concentrations at The Kenoyer South Chat Pile
Tar Creek Superfund Site
Ottawa County, Oklahoma

Figure 13. Total Zinc Concentrations at The Kenoyer South Chat Pile
Tar Creek Superfund Site
Ottawa County, Oklahoma



Neck/ALBA, Snap, Oronogo/duenweg, Joplin, Thoms, Carl Junction, and Waco Designated Areas, Jasper County Site, Jasper County, Missouri (Dames and Moore, 1995). The averages and ranges represent data from several piles, as displayed by the relatively large values for standard deviation and wide range between the maximum and minimum concentrations. Sampling and analysis protocols were different.

TABLE 2. STATISTICAL COMPARISONS OF LEAD (mg/kg) IN RAW CHAT FROM DIFFERENT PILES IN THE TAR CREEK SUPERFUND AREA.

CHEM	LOCATION	NO. Of SAMPLES	MEAN (mg/kg)	STD DEV	MIN (mg/kg)	MAX (mg/kg)
Lead	Baxter Springs/Treece Kansas	16	746	538	100	1,700
	Joplin Missouri	24	476	894	116	3,800
	Oronogo/Duenweg Missouri	58	971	1,261	55	8,000
	Bureau of Land Management	30	830	613	78	2,289

The lead concentrations for 16 chat piles in Ottawa County tested by the BLM (Johnson and Malthotra, 1999) are shown in Figure 14. Figures 15, 16, and 17 show the lead concentrations for chat samples taken in Kansas and Missouri by Brown & Root (Brown and Root, 1995). Figure 18 shows the lead concentrations for several chat piles located in Oklahoma, Kansas, and Missouri all plotted on one graph. The wide range and variability of lead concentrations can be explained partly by the inclusion of sieved chat in the analyses and the analyses conducted over several chat piles with very different lead concentrations.

As shown in Table 1 the average lead, cadmium, and zinc concentrations of the chat at the Kenoyer North Chat Pile, the Kenoyer South Chat Pile, the Ottawa Chat Pile, and the Atlas Chat Pile display some variability between the piles. The variability of the lead within a chat pile appears relatively small when comparing the data within the two Kenoyer chat piles as shown in Figures 8 and 11. This could be due to relatively small standard deviations and the narrow range between maximum and minimum concentrations. However, the difference in lead concentration of chat is relatively large when comparing the average lead concentration between different chat piles as shown in Figures 14 - 18.

Background concentrations of lead, cadmium, and zinc in soils for the region are reported in EPA Region VI *Human Health Media-Specific Screening Levels* (EPA, 2000b) as the following ranges, respectively: 10-18 mg/kg, 0.01-1.0 mg/kg, and 22-50 mg/kg. The concentration of lead, cadmium, and zinc in raw chat are much higher than these values. Zinc and lead concentrations are much higher than the background since these elements are the main components of the ore that was mined.

Figure 14. Total Lead Concentrations Chat Piles from Native American Owned Lands Sampled by The Bureau of Land Management (Johnson and Malthotra, 1999) Tar Creek Superfund Site Ottawa County, Oklahoma

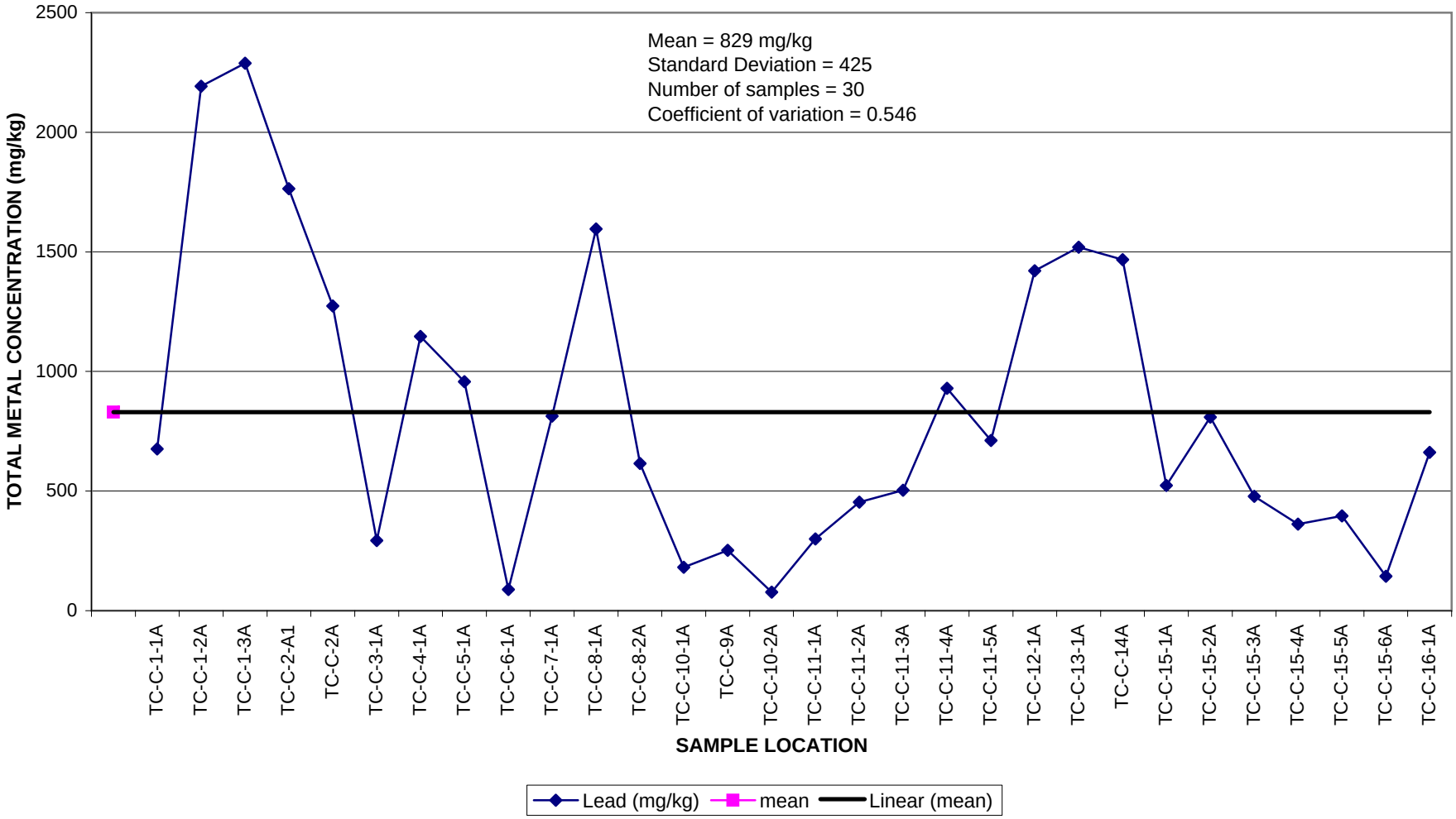


Figure 15. Total Lead Concentrations Chat Piles
Baxter Springs/Treece Kansas Area (Brown and Root, 1995)

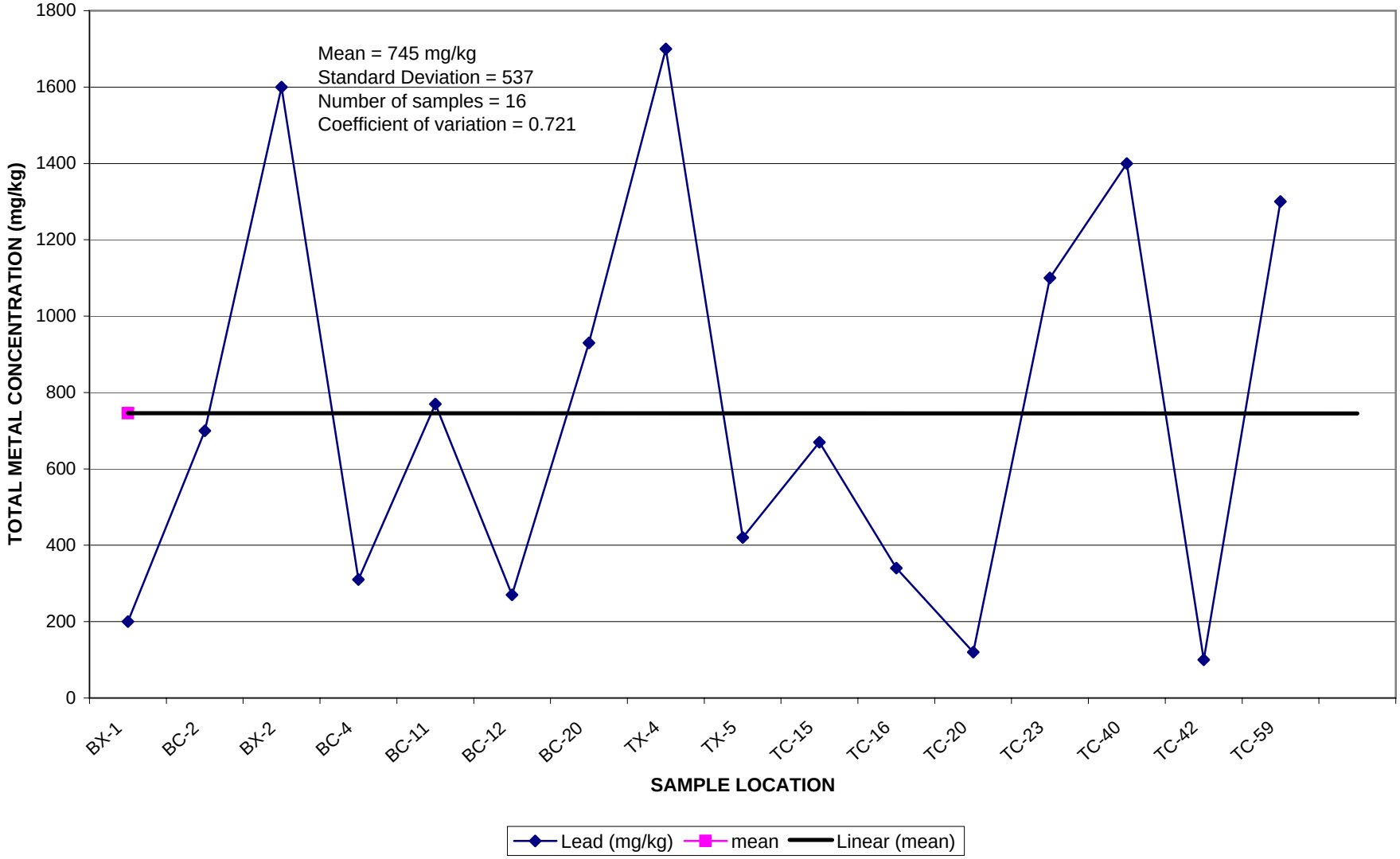


Figure 16. Total Lead Concentrations Chat Piles
Joplin, Missouri Area (Brown and Root , 1995)

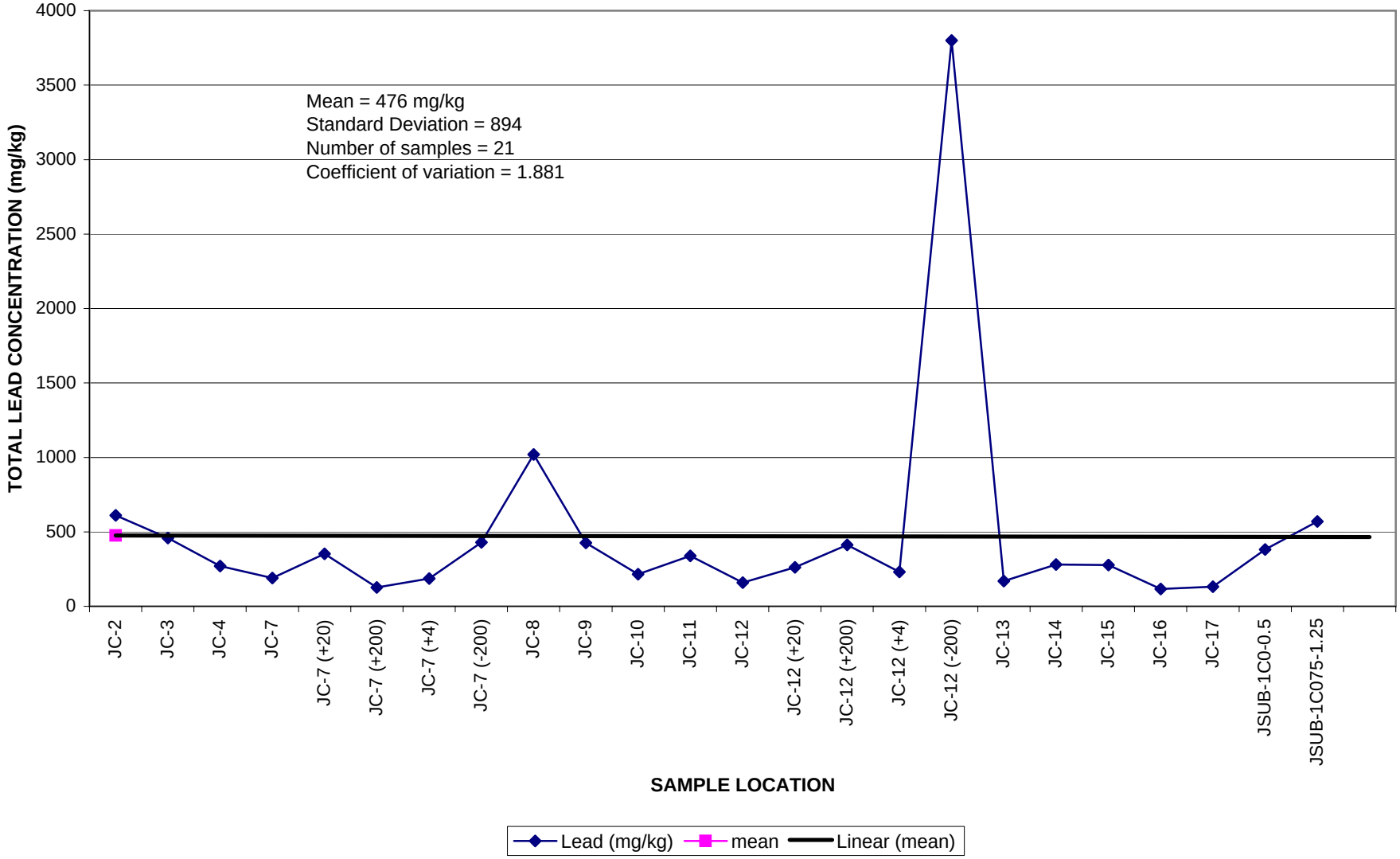


Figure 17. Total Lead Concentrations Chat Piles
Oronogo/Duenweg Area, Missouri (Brown and Root , 1995)

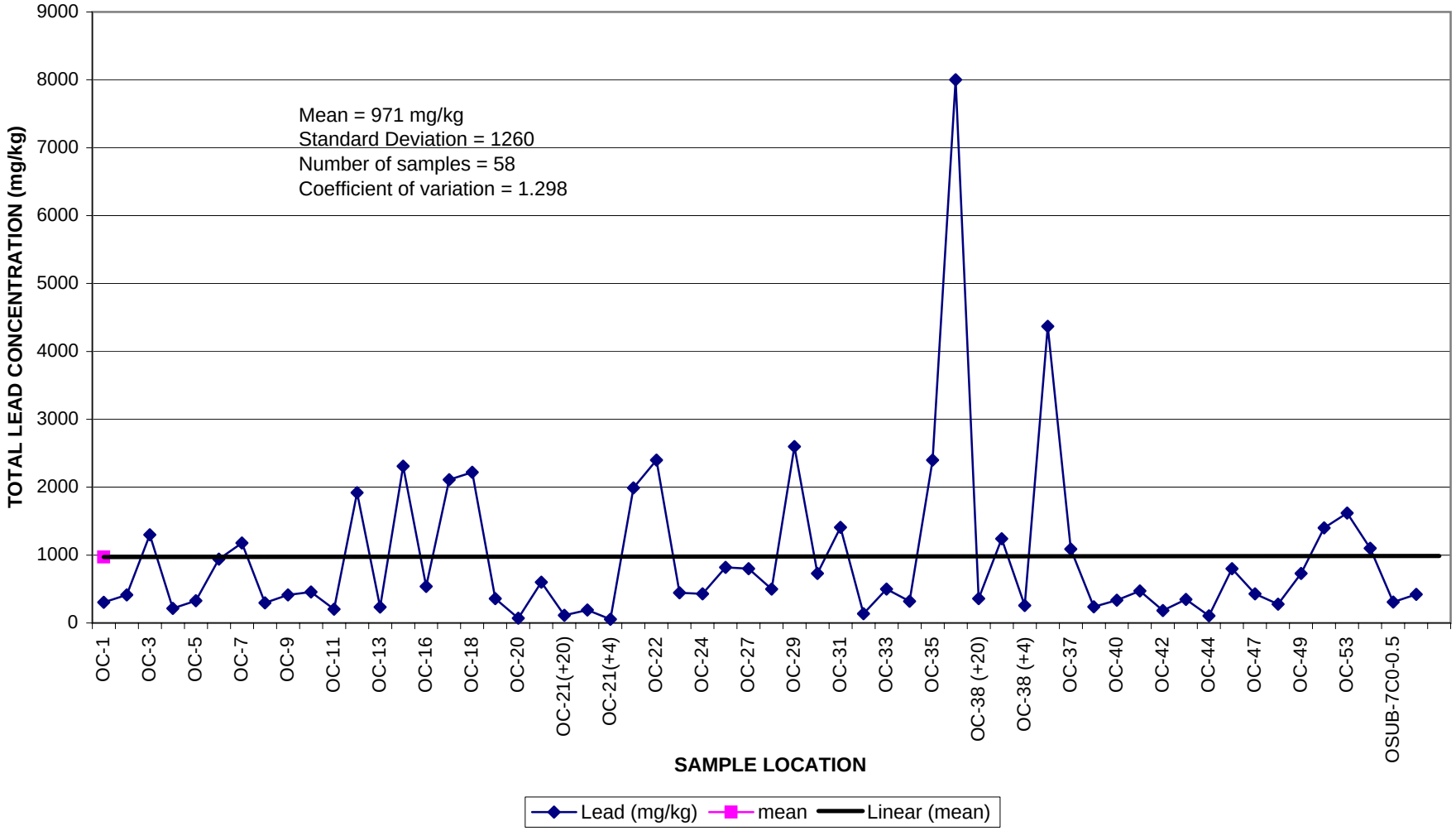
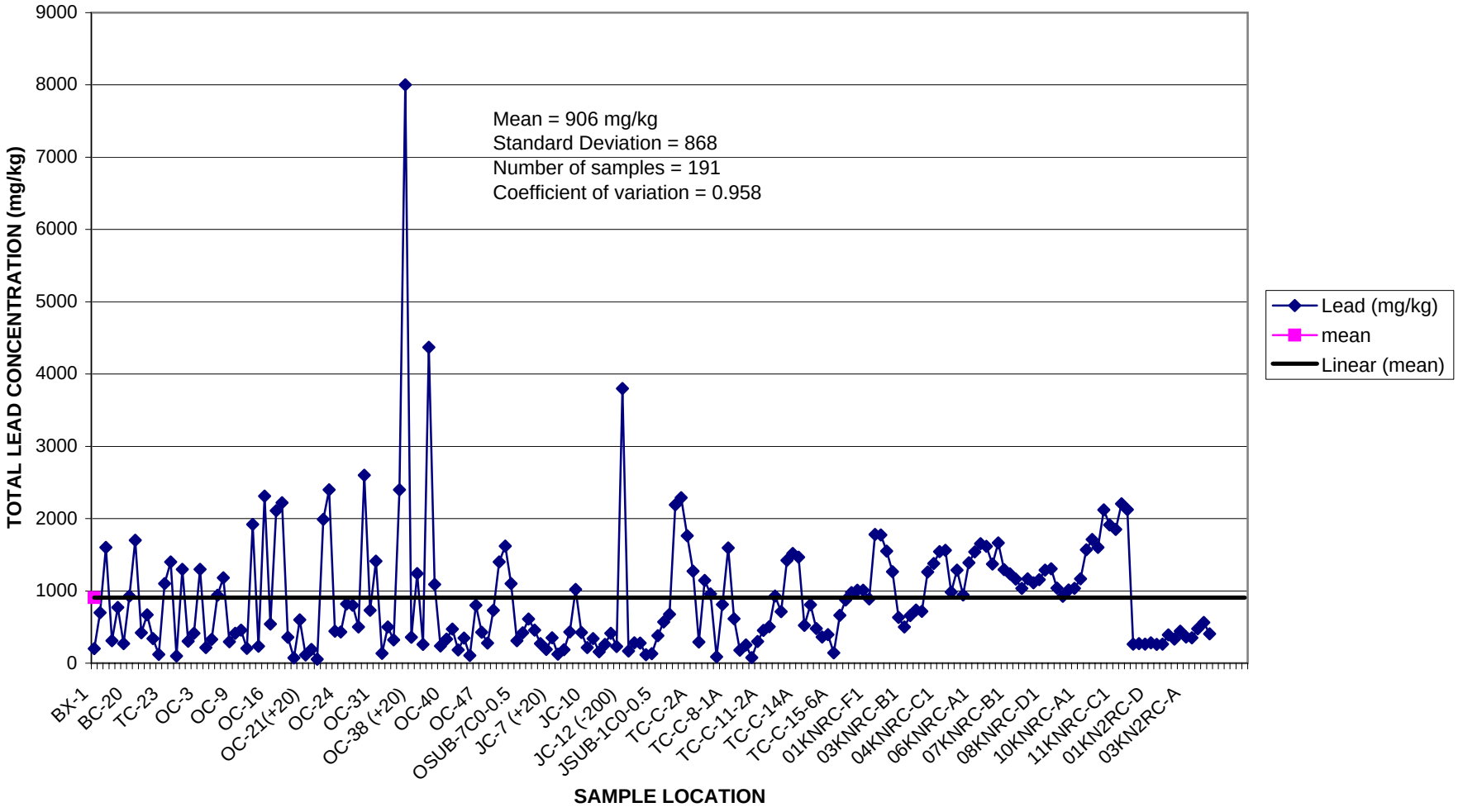


Figure 18. Total Lead Concentrations Chat Piles for Several Chat Piles located in Oklahoma, Kansas, and Missouri (Brown and Root 1995, Johnson and Malthotra 1999, and DEQ)



Mixtures of Materials for Road Usage

Mixtures of materials typically used for road construction were sampled at the Kenoyer North Chat Pile Site to determine the concentration of these other materials to the analysis for Pb, Cd, and Zn. The mixtures of road building materials are described below:

- A pile composed of a mixture of fly ash, river rock and chat was sampled using the front-end loader. Three buckets were taken and four samples were obtained from each for a total of 12 samples.
- A pile containing a mixture of clay and chat was sampled. Three buckets were taken and four samples were obtained from each for a total of 12 samples.
- A pile of hydrated fly ash was sampled using the front-end loader. Only one bucket was taken from this pile and four samples were obtained.
- A duplicate sample was collected for every 10 samples for QA purposes. This resulted in 5 additional samples.

Each composite sample was analyzed by the SEL for total metals concentrations of Pb, Cd, and Zn. The statistics for these samples are presented in Table 3. The analytical results are presented in Appendix C as Tables 7 through 9 for the road mixtures.

TABLE 3. STASTISTICS FOR MIXTURES OF DIFFERENT MATERIALS FOR ROAD USAGE LOCATED AT THE KENOYER NORTH CHAT PILE

	STATISTICS	LEAD (mg/kg)	CADMIUM (mg/kg)	ZINC (mg/kg)
River Rock/Fly Ash/Chat	Mean	872	20	11,730
	N	14	14	14
	Standard Deviation	259	9	4,693
	Minimum	378	8	3,270
	Maximum	1,160	35	19,320
	Median	1,022	22	12,494
	Coefficient of Variation	0.297	0.433	0.400
Clay	Mean	621	20	10,436
	N	14	14	14
	Standard Deviation	194	5	3,181
	Minimum	430	8	6,151
	Maximum	1,067	27	17,174
	Median	530	22	9,788
	Coefficient of Variation	0.312	0.267	0.305
Fly Ash	Mean	222	3	386
	N	5	5	5
	Standard Deviation	7.6	0	19.5
	Minimum	209	3	366
	Maximum	228	3	411
	Median	223	3	383
	Coefficient of Variation	0.034	0.086	0.050

Ottawa County Roads

Three roads located in Ottawa County were sampled (see Figure 1). The purpose for sampling these roads was to determine the lead, cadmium, and zinc composition of the road where either chat was used or chat mixed with other materials was used. These represent a small sampling set of all the roads where chat has been placed within the Tar Creek Superfund Site. A separate report with results from sampling of ground asphalt containing chat was prepared by DEQ (DEQ, 2000). Three part composites were taken at each sample location composed of grabs from both sides and the middle of the road. Three composite samples were taken 1,000 feet apart on Douthat Road centered at the bridge crossing at Tar Creek. Two composite samples were collected at the intersection of S590 Road and E20 Road (one sample and a duplicate). Two composite samples were collected on S590 road 1,000 feet north and south from the intersection with E30 road. Two composite samples were collected on E30 road in front of a driveway located approximately 2,500 feet west of the intersection with S590 road (one sample and a duplicate).

Each composite sample was analyzed by the SEL for total lead, cadmium, and zinc. The statistics for these samples are presented in Table 4. This data is presented in Appendix C as Table 10 for the roads. A mixture of other materials including river rock and clay were observed with the chat gravels at several road locations.

TABLE 4. STATISTICS FOR INDIVIDUAL ROADS LOCATED IN OTTAWA COUNTY (Sampled on September 6, 2000 by the Oklahoma Department of Environmental Quality).

	STATISTICS	LEAD (mg/kg)	CADMIUM (mg/kg)	ZINC (mg/kg)
Roads	Mean	279	25	4,875
	N	9	9	9
	Standard Deviation	169	10	2,048
	Minimum	118	14	2,572
	Maximum	555	41	8,368
	Median	229	22	4,894
	Coefficient of Variation	0.605	0.412	0.420

Sieve Analyses

Twelve samples of chat were collected from the Ottawa and Atlas chat piles along with two duplicates (DEQ, 2000). These piles are located near Picher, Oklahoma; the Ottawa pile is north and the Atlas pile is east (Figure 1). Standard Testing Laboratory in Oklahoma City performed gradation analyses of composite samples of raw chat from each pile. Samples from each of the sieves were collected (totaling twelve) and one duplicate of the #40 sieve for each pile was analyzed for lead, cadmium, and zinc concentrations by the SEL.

Figure 19 shows the gradation curves for the two raw chat samples at sites 01 and 06 from the Kenoyer North chat pile and the raw composited chat from the Ottawa and Atlas chat piles. These curves show similar trends. The uniformity coefficients (8.2 versus 12.3) and the coefficients of gradation (1.2 versus 1.73) are similar for the two samples of raw chat from the

Kenoyer pile indicating similar distribution on the surface and within a chat pile. These indices also compare to those in the Kansas and Missouri as well as at the Atlas and Ottawa Chat piles in Oklahoma. Gradation curves for chat in Baxter Springs/Treece Kansas (Dames and Moore, 1993) and for Jasper County, Missouri (Dames and Moore, 1995) are presented in Figures 20 and 21, respectively.

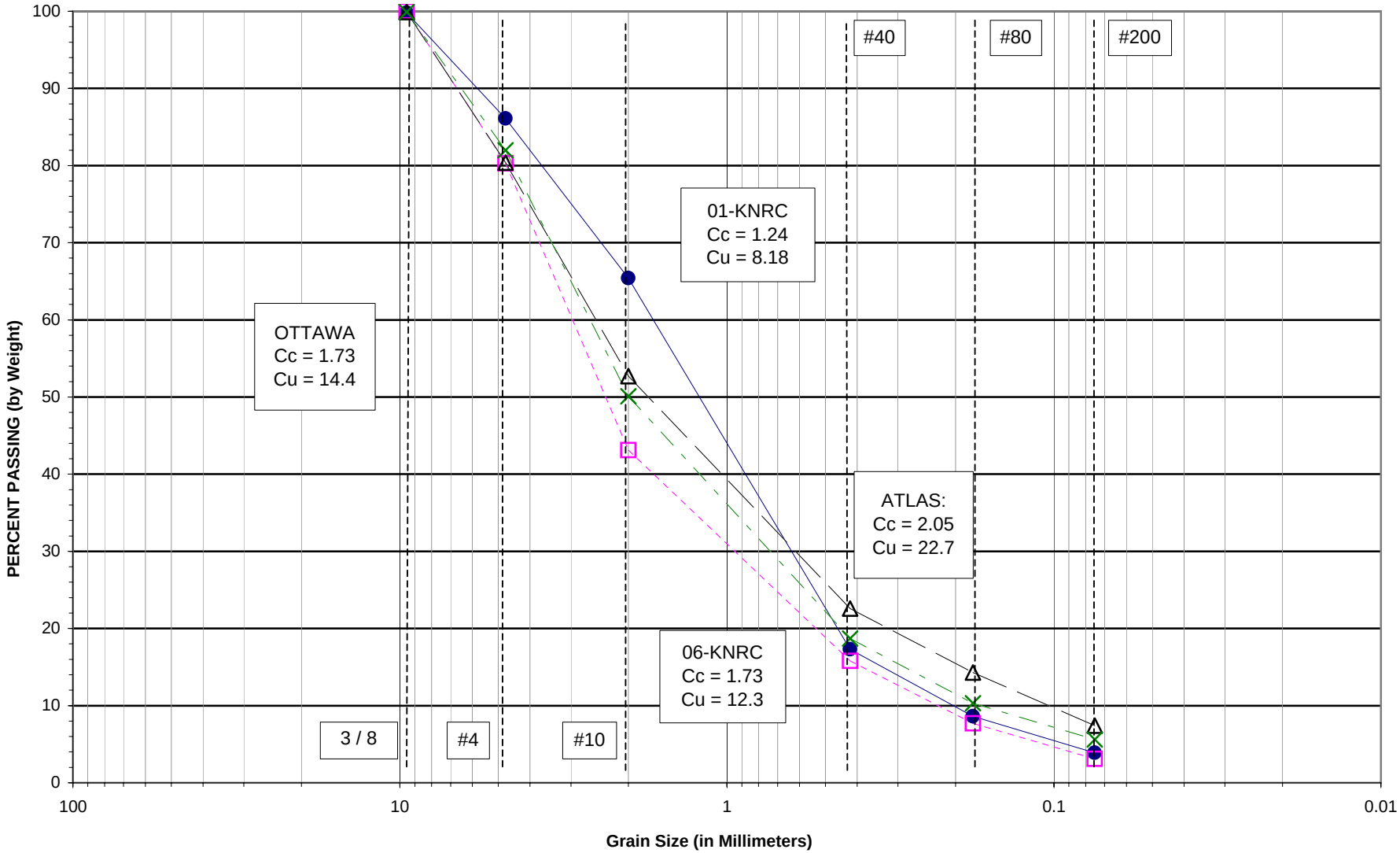
The complete data set for the sieved samples is presented in Table 11 of Appendix C. Figures 22, 23, and 24 show grain size distribution versus Pb, Cd, and Zn for the two raw chat samples at sites 01 and 06 from the Kenoyer North Chat Pile and composited chat samples from the Ottawa and Atlas Chat piles, respectively. The chat particles display similar distributions at the different chat piles. Most of the mass of chat is retained on the #4, #10, and #40 sieves and less than 20% of the chat passes the #40 sieve (#80, #200 and pan). This corresponds to the Eagle-Picher milling process report where only that material that passed the #35 sieve was processed and that greater than #35 sieve was disposed of as tailings waste on the chat pile (Isern, 1943).

Lead concentrations for the sieved samples of chat from the Kenoyer North pile ranged from 68 (+#4 sieve) to 3,146 (-#200 sieve) mg/kg for site 01 and from 85 (+#4 sieve) to 7,068 (-#200 sieve) mg/kg for site 06. The average lead concentrations at the two sites for raw chat are 874 and 1,485 mg/kg, respectively. The lead concentrations for the sieved samples of chat from the Ottawa chat pile ranged from 70 (+#4 sieve) to 6,668 (-#200 sieve) mg/kg. The lead concentrations of the sieved samples of the Atlas Chat ranged from 25 (+#4 sieve) to 1,789 (-200 sieve) mg/kg. The average lead concentration of raw chat was 314 mg/kg at the Atlas Pile and 732 mg/kg for the Ottawa Chat. The highest lead, cadmium, and zinc values are concentrated in the smallest particle sizes (minus #200 sieve) and the lowest values are from the largest particle sizes (plus #4 sieve) as can be seen in figures 22-24.

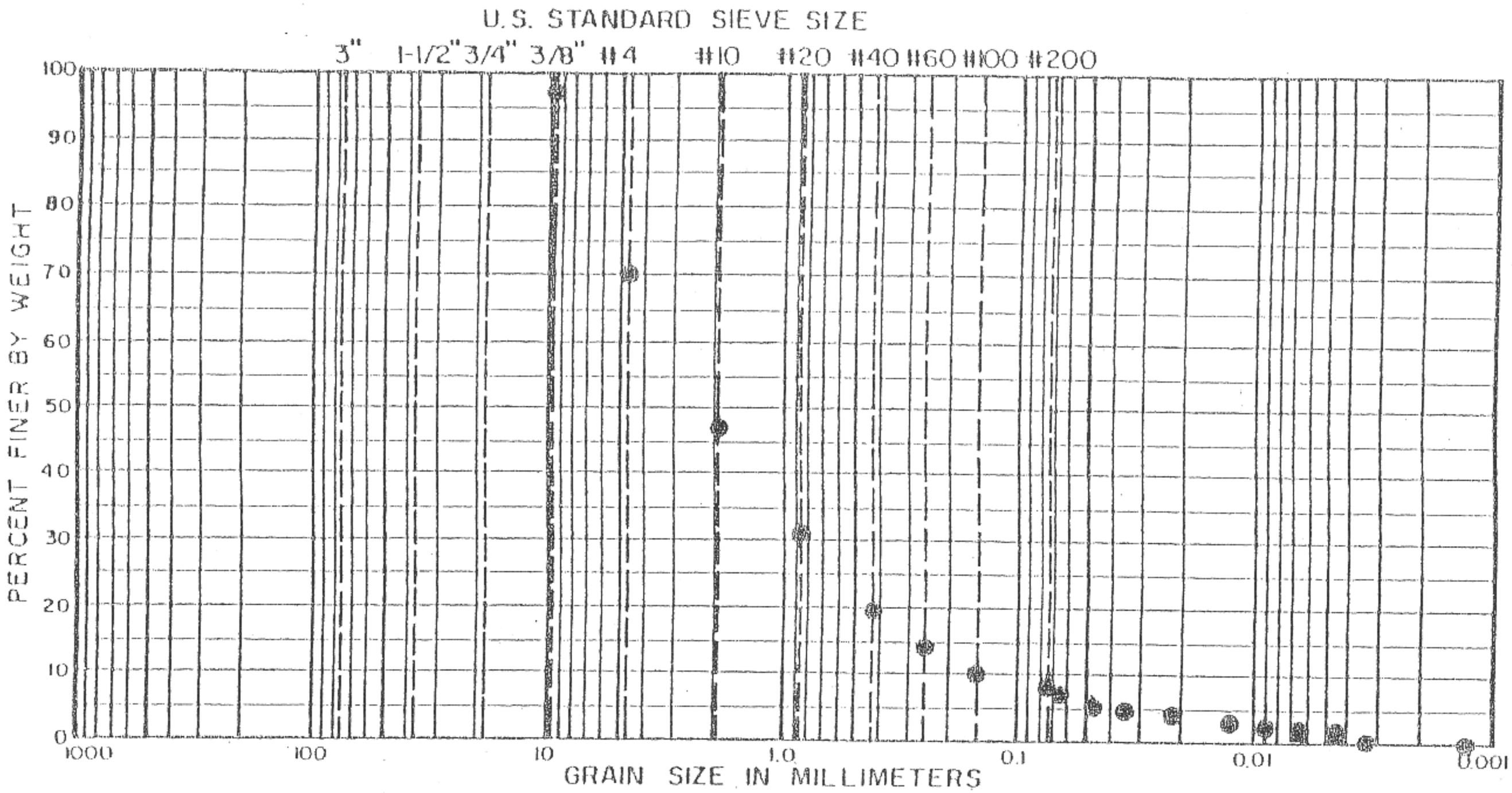
Figure 22 shows the lead concentration of the different sieve sizes for Kenoyer North (sites 01 and 06), the Ottawa and Atlas chat piles. The most obvious feature is the increasing heavy metal concentration (lead in this case) with decreasing particle size. This trend is repeated over and over in subsequent graphs. The curves for the Kenoyer North (Site 06) and the Ottawa chat piles display similar trends. The curve for the Atlas pile shows the lowest concentrations and that of the Kenoyer North (Site 01) is intermediate to Kenoyer North Site-06 and the Ottawa. The two curves for the Kenoyer North pile (Sites 01 and 06) diverge significantly, especially at the particle sizes below the #40 sieve. This indicates that the lead concentration varies within a pile even though the particle size distribution tends to remain consistent throughout a pile. Site 06 is taken from a location within the center of the pile (albeit from an open, working face) and contains higher lead concentrations in the smaller particle sizes than Site 01, which is located at the outer edge of the pile. This suggests that the lead may migrate and concentrate near the center of the chat piles. However, more testing is required to support this conclusion.

Graphs of cadmium and zinc concentrations versus particle size for the Kenoyer North (Sites 01 and 06), the Ottawa and Atlas chat piles are shown on Figures 23 and 24, respectively. This shows that the cadmium and zinc concentrations increase with decreasing particle size similar to lead. The concentrations of cadmium at the Ottawa and Atlas chat piles are higher than those at the Kenoyer for the minus #200 sieve sized particles. The Kenoyer North Site 01 displays higher cadmium concentration for the fine-sized particles than at the Kenoyer North Site 06, a reverse

Figure 19. Particle Size Analysis of Chat
Kenoyer North, Atlas, and Ottawa Chat Piles
Tar Creek Superfund Site
Ottawa County, Oklahoma



Uniformity Coef: Cu = D60 / D10
Coef of Gradation: Cc = (D30)^2 / (D60 x D10)



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

LOCATION	DEPTH	CLASSIFICATION
TC-OTT	Bulk-Cherokee	BULK CHAT: BAXTER SPRINGS/TREECE

Figure 20. Particle Size Analysis of a chat pile located near Baxter Springs/Treece, Kansas (Figure 4.2.1 in Dames and Moore, 1993).

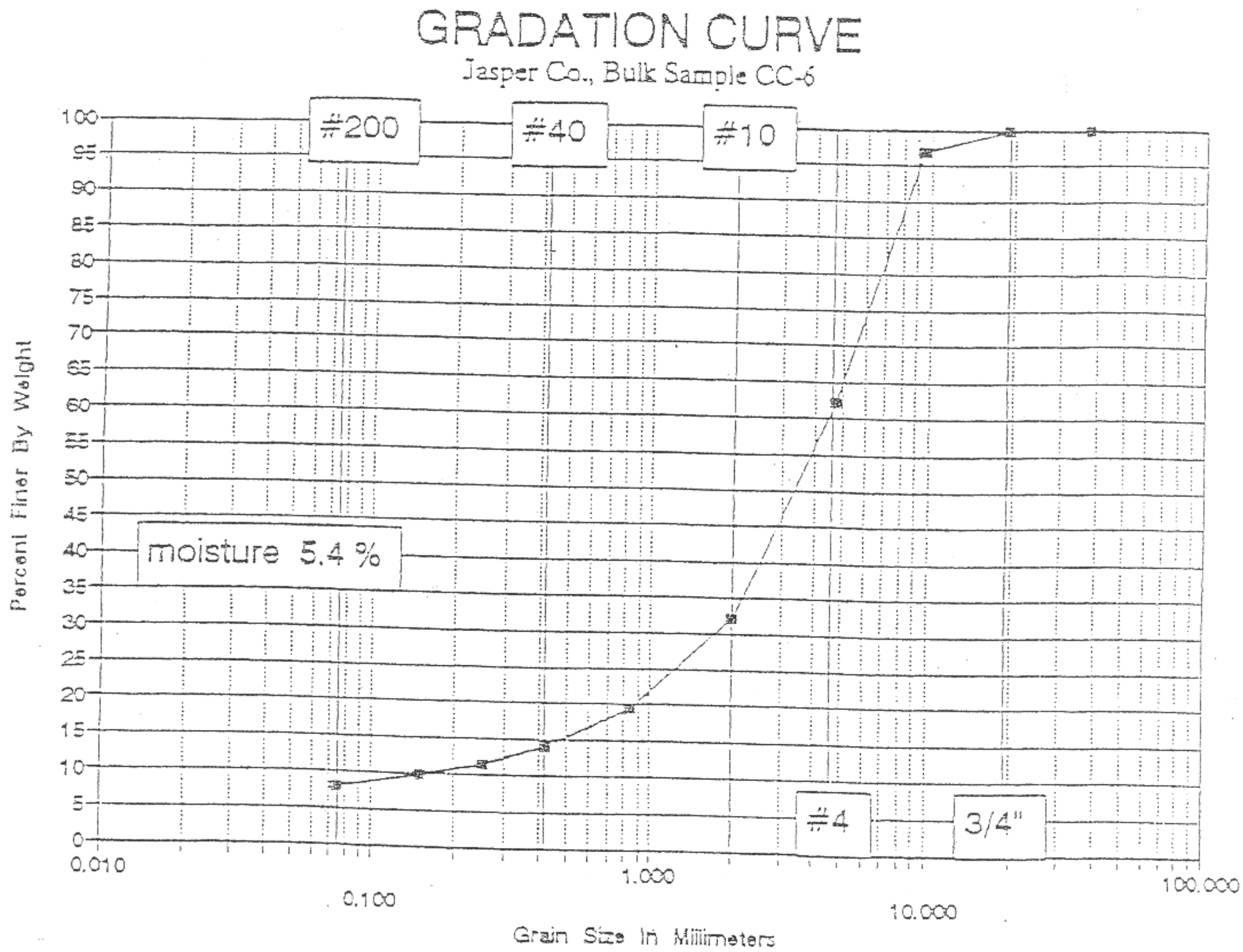


Figure 21. Particle Size Analysis of a chat pile located in Jasper County, Missouri (Figure 4-1 in Dames and Moore 1995).

Figure 22. Particle Size of Chat versus the Percent Passing and the Total Lead Concentration
Kenoyer North, Atlas, and Ottawa Chat Piles
Tar Creek Superfund Site

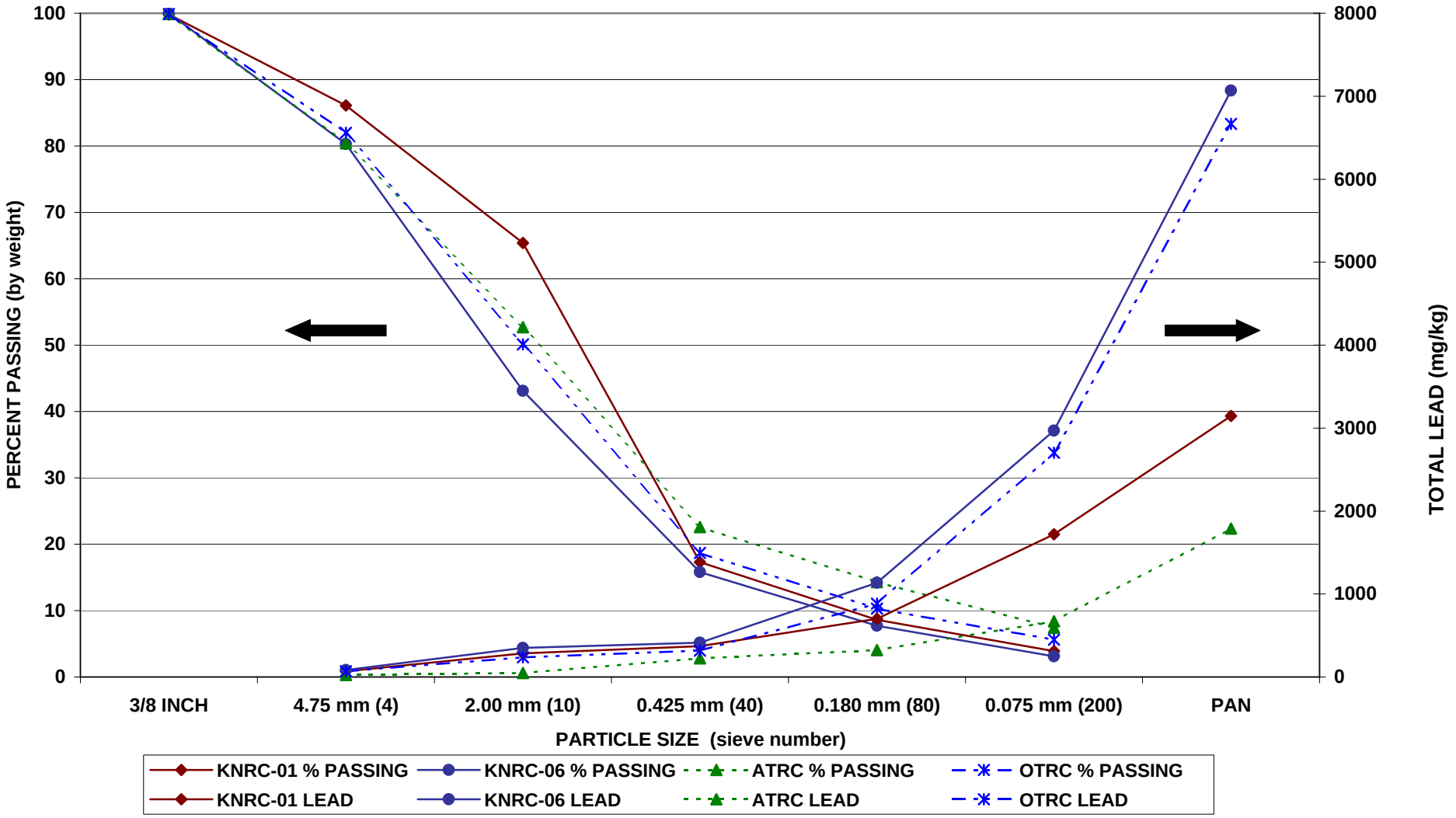


Figure 23. Particle Size of Chat versus the Percent Passing and the Total Cadmium Concentration
Kenoyer North, Atlas, and Ottawa Chat Piles
Tar Creek Superfund Site

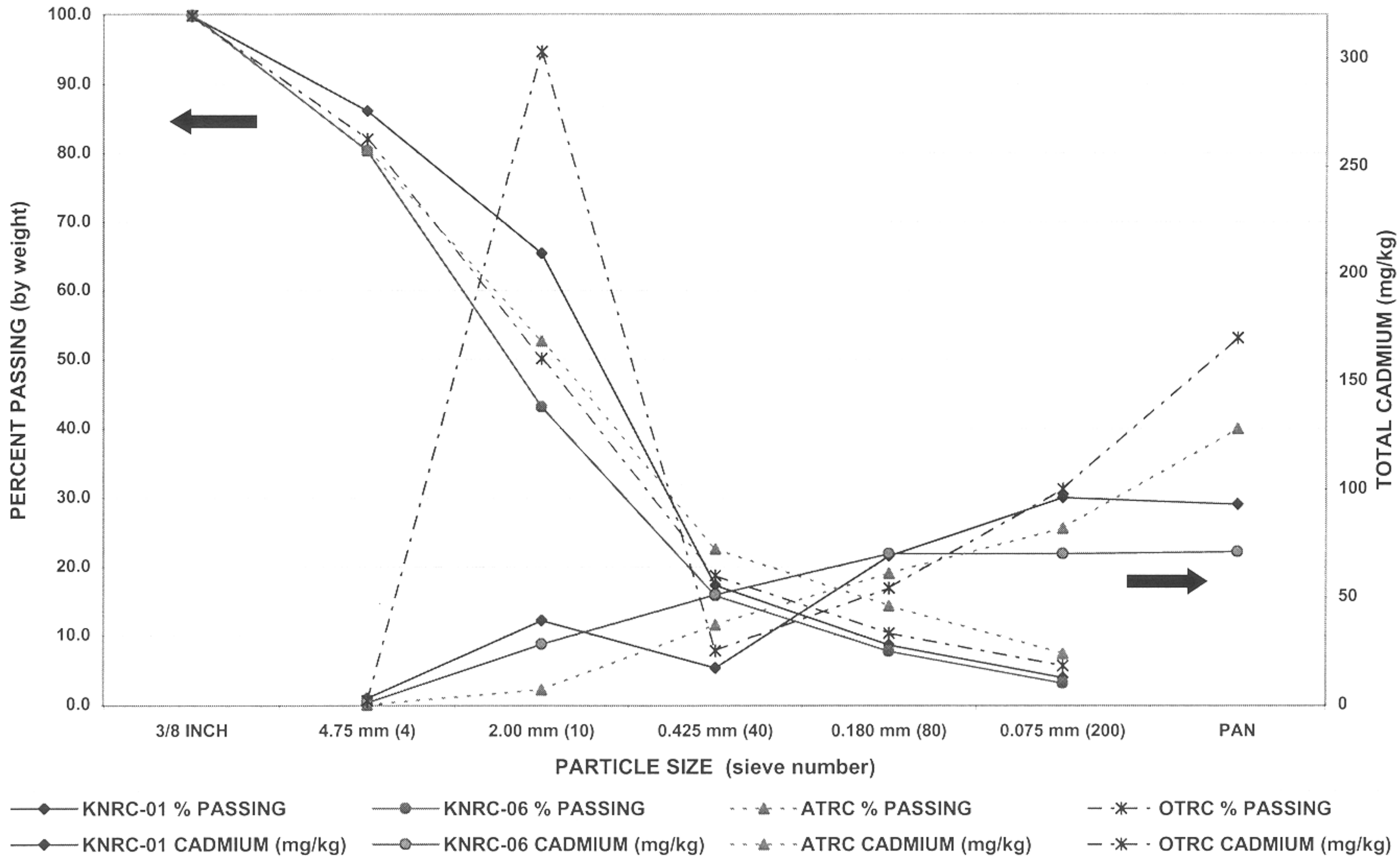
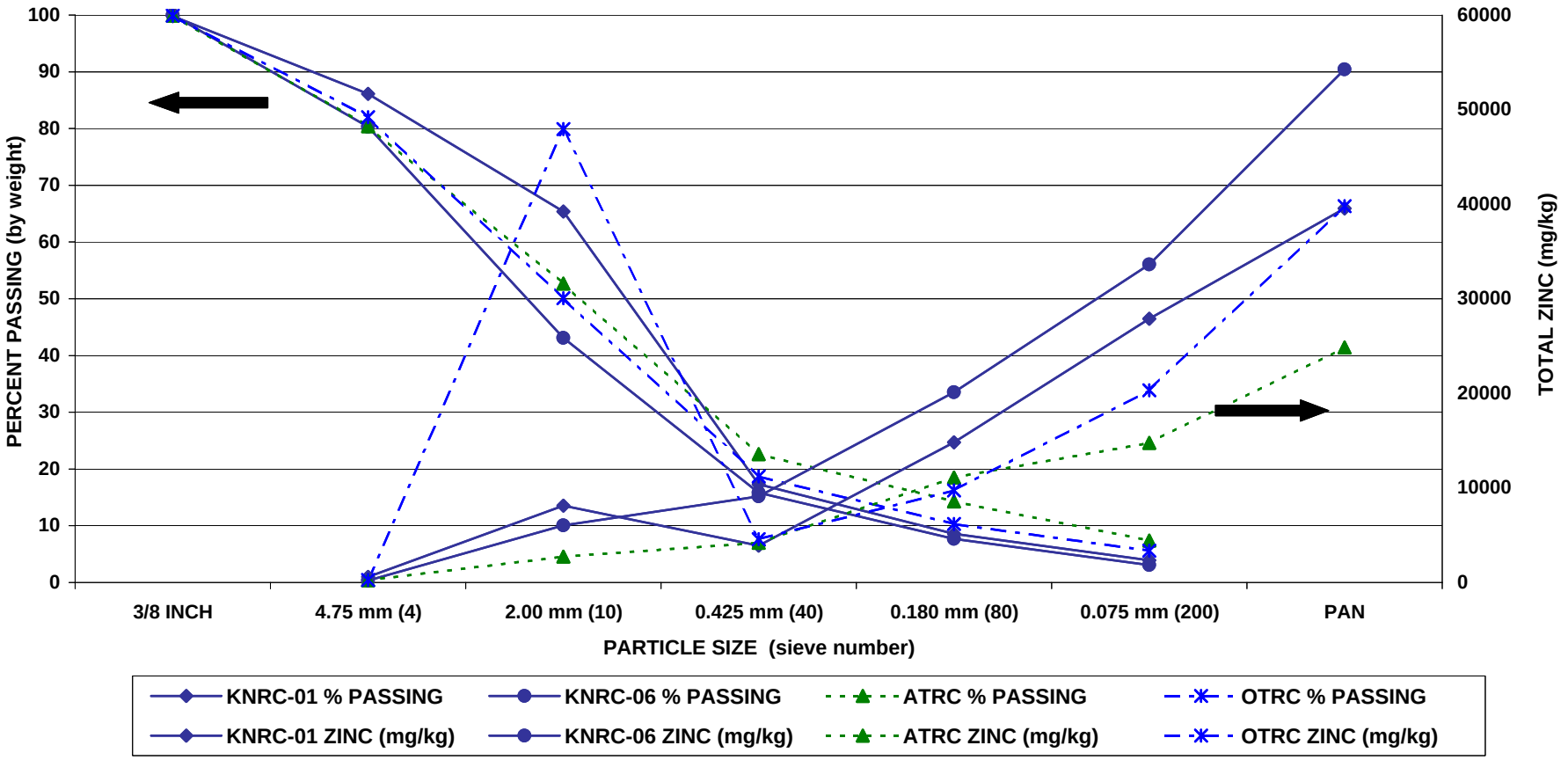


Figure 24. Particle Size of Chat versus the Percent Passing and the Total Zinc Concentration
Kenoyer North, Atlas, and Ottawa Chat Piles
Tar Creek Superfund Site



of the lead trend. Conversely, the zinc concentrations at the Kenoyer tend to be slightly higher than at the Ottawa and Atlas chat piles for most particle sizes. The results of sampling appear to demonstrate that heavy metals (lead and zinc) concentrate in the fine material and center of a chat pile. This is partially supported by Figures 22 and 24 where the curves for lead and zinc concentrations of the fine-sized particles at Site 06 are slightly higher relative to those at Site 01.

The BLM data (Johnson and Malthotra, 1999) for particle size versus lead concentration shown in Figure 25 has the same trend as the data presented in Figure 19 for the Kenoyer North, Ottawa, and Atlas Chat Piles. That is, lead concentrations increase with decreasing particle size. This figure represents the average lead concentration for 30 samples of 5 size fractions of chat material [<250 um (#60), 250um - 1mm (#16), 1mm - 2 mm (#10), 2mm - 4.75mm, and >4.75mm (#4)] as shown in the Table 11 of the Appendices. The chat came from 16 chat piles in Ottawa County owned by Native Americans.

Calculating the lead mass in each size fraction can assess the effect of particle size on overall lead concentration of chat. This is given by the concentration multiplied by the weight percentage of chat for each corresponding particle size. The lead mass per kilogram of raw chat can be summed to get the total lead concentration and compared to the raw chat analytical results. This can be used to assess the influence of each particle size on the total Pb, Cd, and Zn concentration. Figure 26 shows the mass of lead distribution at the Kenoyer, Atlas and Ottawa chat piles. Significant amounts of lead are present on the #10 and #40 sieves. This is due to the large volume of coarse materials with small lead concentrations. More than half of the lead, and up to 87%, resides in the fine material, <0.425 mm passing the #40 sieve. This represents less than an average of 20% of the chat volume, by weight.

Lead concentrations of raw chat were calculated for the sieved material at the two Kenoyer North sites using the sum of the products of the individual mass fractions multiplied by their concentration. There is a good correlation of calculated and measured lead concentration values of raw chat for the data from Kenoyer Site 01, Ottawa, and Atlas but not for Kenoyer Site 06 and the reason for the difference is unknown. The average calculated value at Kenoyer site 06, 678 mg/kg, which is low compared to the actual measured value of 1485 and 796 mg/kg from SEL and EPAHL, respectively. The average calculated lead value for raw chat at Site 01, 502 mg/kg is within the range of measured values of 874 and 452 mg/kg from SEL and EPAHL, respectively but tends toward the low end.

Figure 25. Particle Size Chat versus Percent Passing and Total Lead Concentration Collected by the Bureau of Land Management (Reference 10 1999)

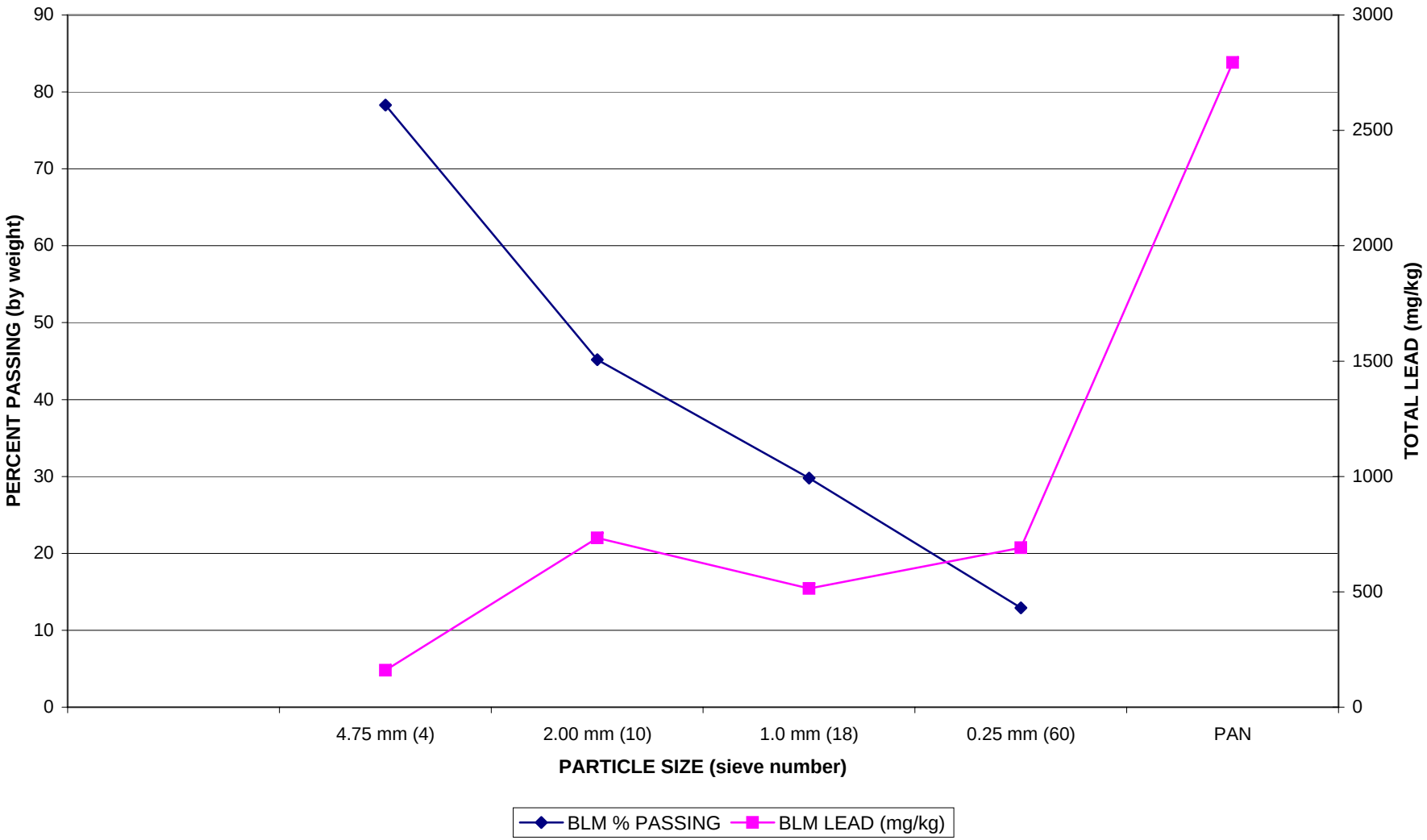
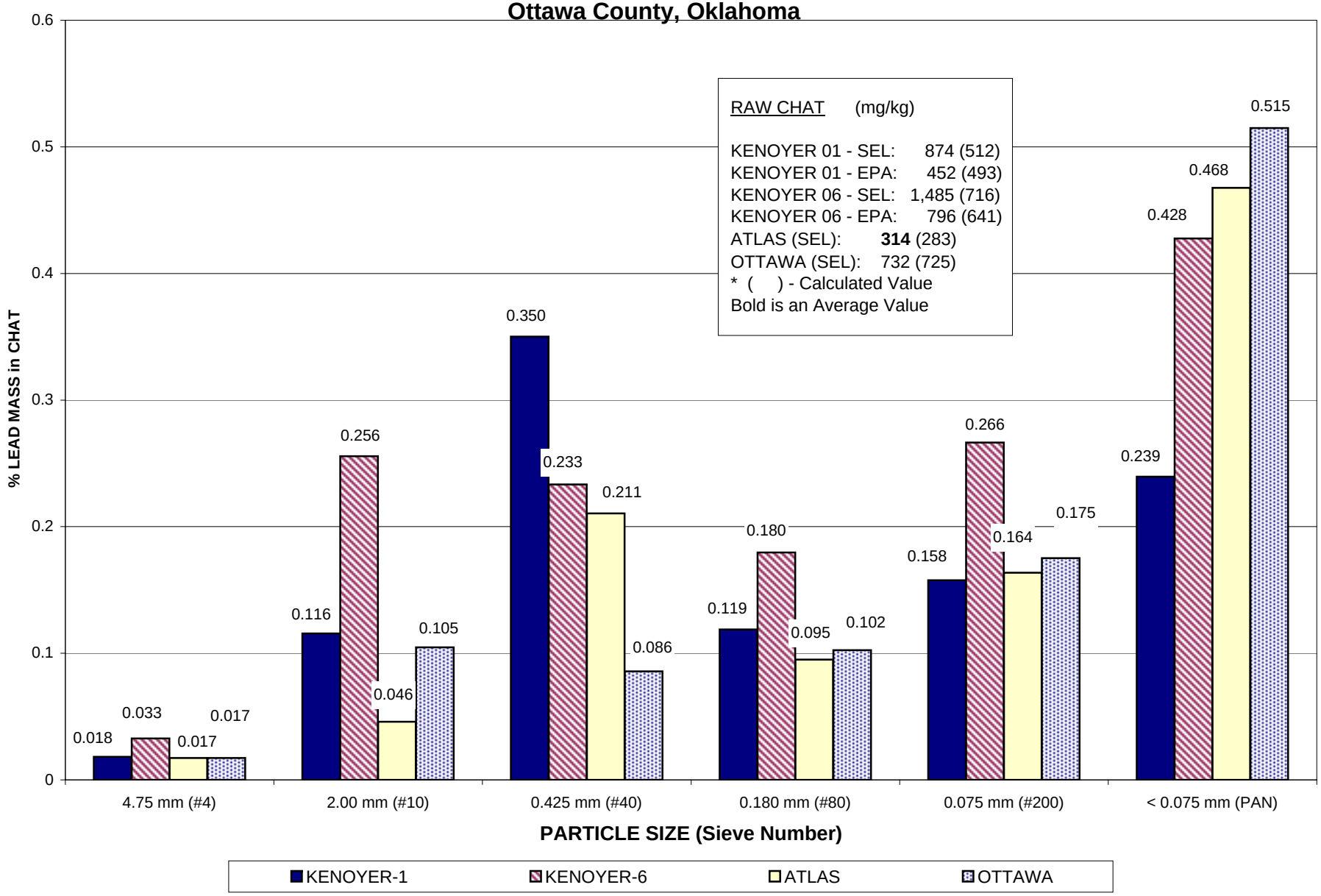


Figure 26. Mass Distribution of Lead in Chat
Kenoyer North, Atlas & Ottawa Chat Piles
Tar Creek Superfund Site
Ottawa County, Oklahoma



Data comparison of two different laboratories for Sieved Chat

The State Environmental Laboratory (SEL) and the EPA Houston Laboratory analyzed each size fraction of the sieved samples and two duplicates from the Kenoyer Chat Pile for total lead, cadmium, and zinc. The two duplicate samples were collected from the #80 sieve for QA conformance.

The lead, cadmium and zinc concentrations measured by two laboratories independently for the sieved raw chat samples at the Kenoyer North Site-01 and Site-06 are presented in the Table 12 of Appendix C. The values for ½" sieve size are not presented because 100% of the material passed thru. The analytical data for the sieved chat from the Ottawa and Atlas piles are shown in Table 11 of Appendix C.

The analytical results for lead, cadmium, and zinc concentrations of the sieved chat were compared between two different laboratories. They are presented in Figures 27-29 and show the distribution of metal concentrations for each sieve size tested independently by the two laboratories for Kenoyer North Chat Pile Sites 01 and 06. The predominant feature of these figures is the increasing metal concentration with decreasing particle size. Also, when the curves for the site 01 and site 06 are compared to one another it is apparent that the Site 06 has higher lead and zinc concentrations in the finer sized particles (#80 sieve – pan). The differences in lead, cadmium, and zinc concentrations measured by each lab for the individual particle sizes appear to be relatively small and the laboratory analyses are comparable.

Quality Assurance / Quality Control

Sample duplicates were collected one per every ten samples. No field or trip blanks were collected since the chat samples were analyzed for lead, cadmium, and zinc concentrations only. The duplicates show the reproducibility of the analyses.

Figure 27. Data from the Oklahoma SEL and the EPA Region VI Houston Laboratory for analysis of Total Lead Concentrations for Kenoyer North Chat Pile.
Tar Creek Superfund Site
Ottawa County, Oklahoma

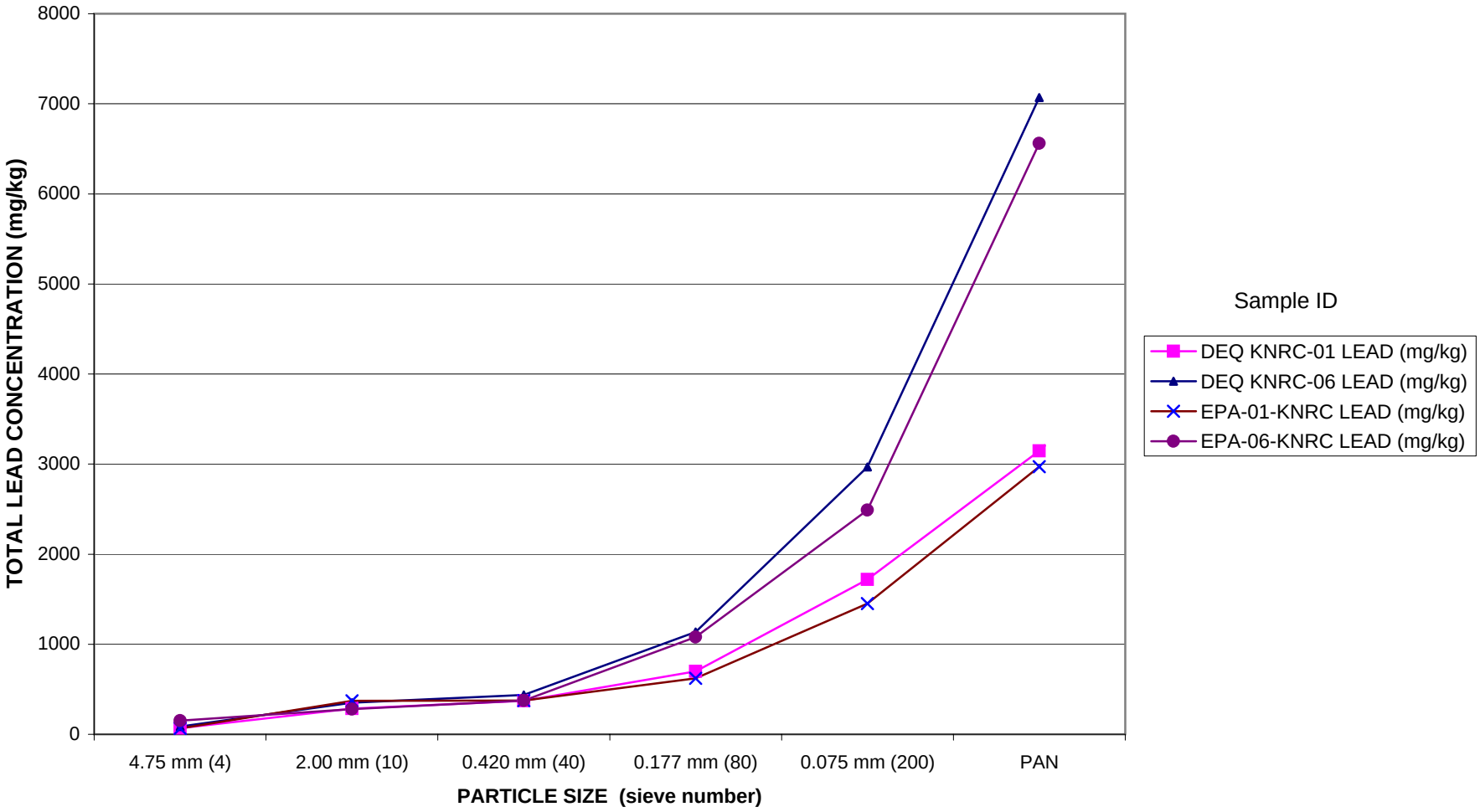


Figure 28. Data from the Oklahoma SEL and the EPA Region VI Houston Laboratory for analysis of Total Cadmium Concentrations from the Kenoyer North Chat Pile Tar Creek Superfund Site Ottawa County, Oklahoma

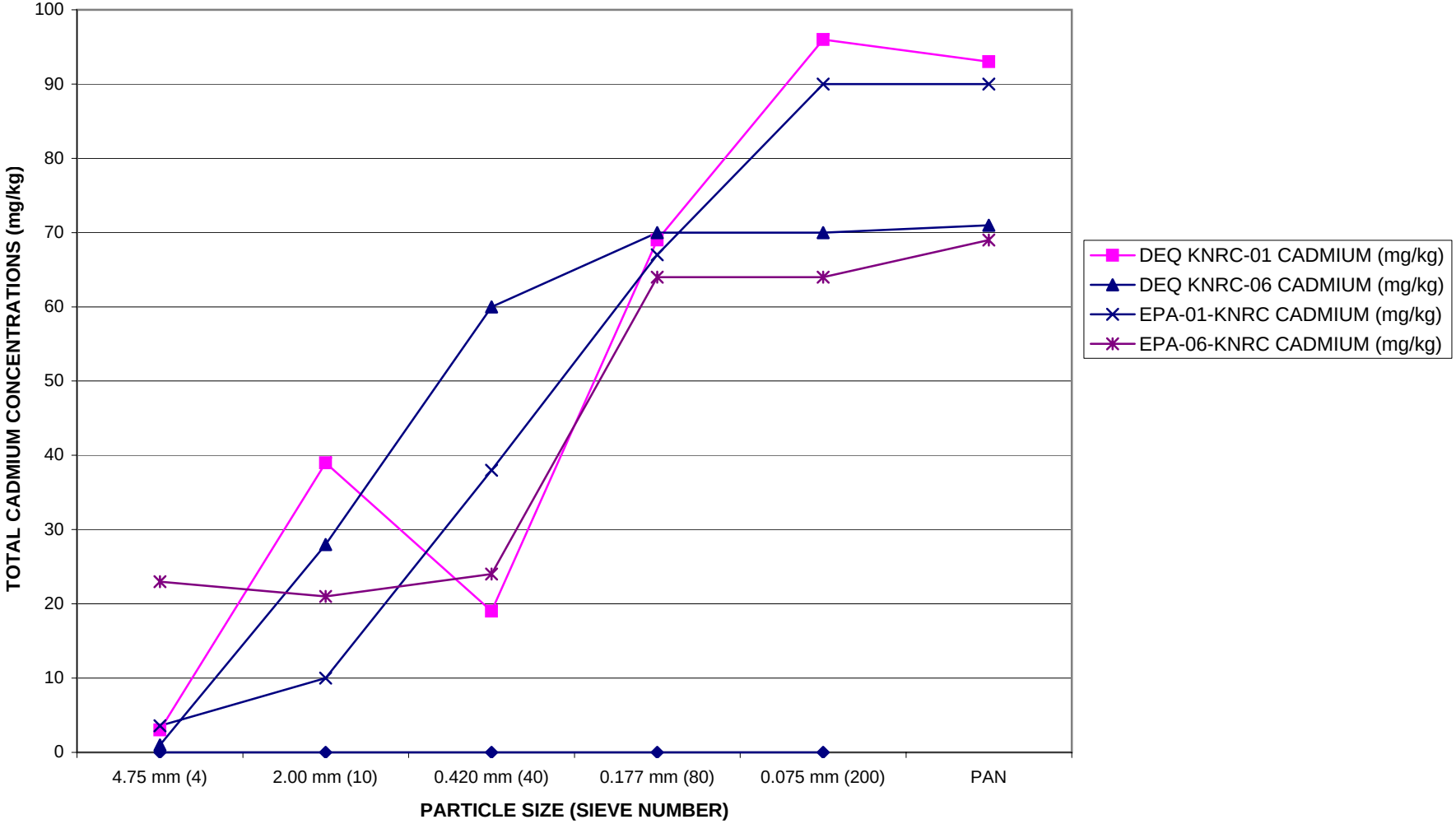
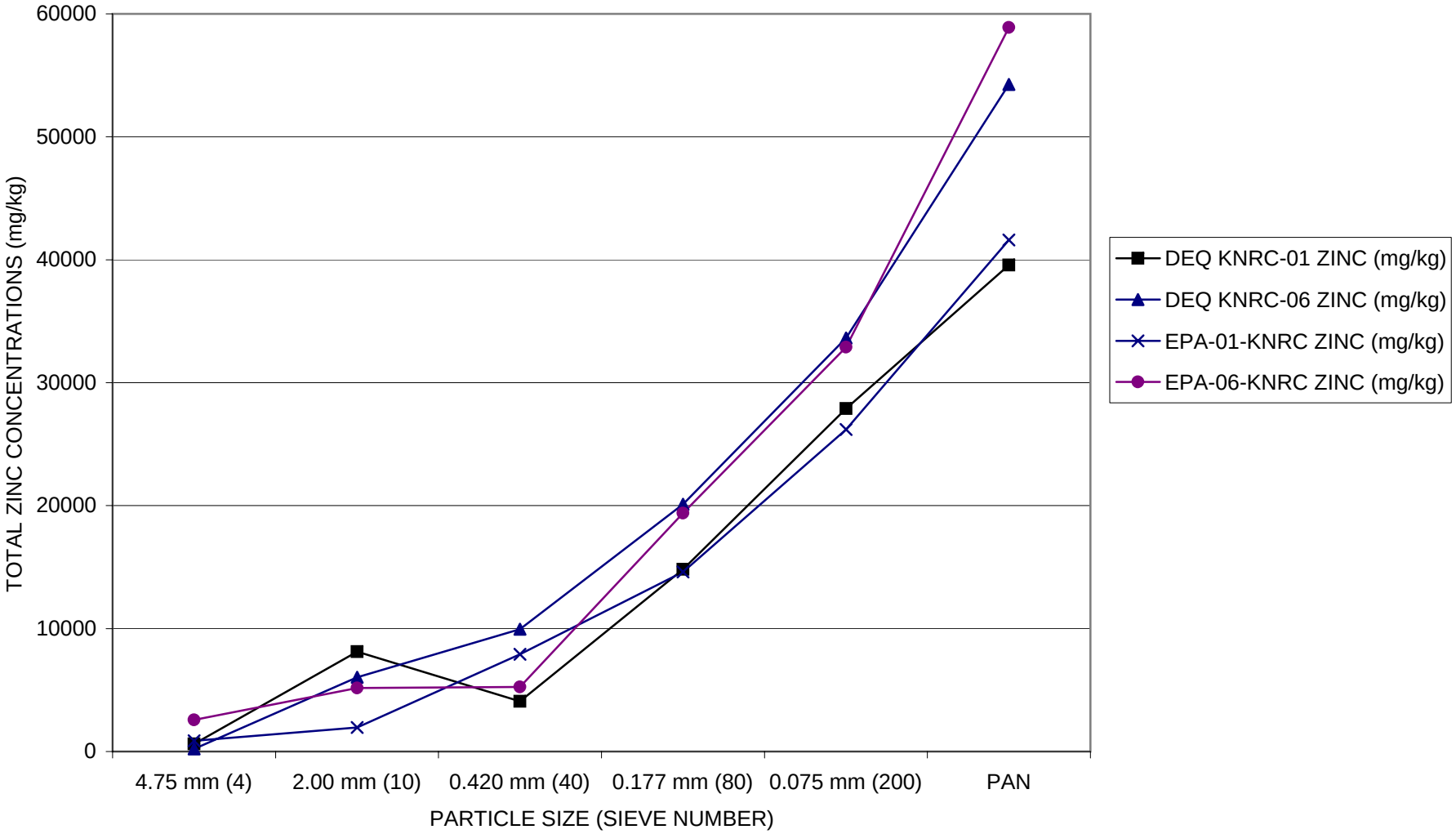


Figure 29. Data from the Oklahoma SEL and the EPA Region VI Houston Laboratory for analysis of Total Zinc Concentrations from the Kenoyer North Chat Pile.
Tar Creek Superfund Site
Ottawa County, Oklahoma



Number of Samples

One purpose of this study was to determine the number of samples needed to characterize a chat pile. Equation 1 gives the number of samples required to identify a population mean within a certain level of confidence when the population variance is unknown (Appendix B). This equation uses a sample mean and variance to calculate the number of samples required to identify a population mean. It also assumes that the data is normal. Table 5 presents the results for calculation of the number of samples using Equation 1 for various chat piles. The number of samples needed to statistically characterize the Kenoyer North Chat Pile was calculated to be 10 for lead. The number of samples needed to adequately characterize the Kenoyer South pile was calculated to be 9. The volume of chat at the Kenoyer North and Kenoyer South chat piles is 1,201,221 and 29,342 cubic yards, respectively (USACE, 1999). Using the volumes and number of samples required, the volume of chat represented per sample is calculated as 120,122 and 3,260 cubic yards respectively for the Kenoyer North and South chat piles. This is such a large range that the usefulness of these values is uncertain and may be specific for each chat pile.

Equation 1 was used to analyze the data from Kansas, Missouri, and the BLM data for Native American owned chat piles in Oklahoma. Results are shown in Table 5. The number of samples required is much larger than for the Kenoyer piles. One of the differences between the Kansas, Missouri, and BLM data and the data for the Kenoyer North and South piles is that the standard deviation is much greater in the Kansas, Missouri, and BLM piles. The numbers from the Kansas, Missouri, and BLM represent several different piles and some sieved chat whereas the Kenoyer North and Kenoyer South piles are single piles. Variability between piles appears greater than within a single pile, which could be one reason for a larger number of samples.

TABLE 5. CALCULATED NUMBER OF SAMPLES FOR VARIOUS CHAT PILES

CHAT PILE	MEAN (mg/kg)	STANDARD DEVIATION	NUMBER SAMPLED	CALCULATED SAMPLE NUMBER[3], n
Kenoyer North	1,314	389	49	10
Kenoyer South	352	95	14	9
Joplin, Missouri [1]	476	894	24	399
Oronogo/Duenweg, Mo [1]	971	1261	58	190
Baxter Springs/Treece, Ks [1]	746	538	16	59
BLM [2]	830	453	30	34
Tar Creek RI/FS Workplan [1]	626	875	140	221

References for this table:

1) Brown and Root Environmental, July, 1995, "Sampling and Analysis Plan Mining Waste Remedial Investigation/Feasibility Study Tar Creek Superfund Site, Ottawa County, Oklahoma." Prepared for the US Army Corps of Engineers Tulsa District and U.S. Environmental Protection Agency Region VI, Appendix C1.
2) C. C. Johnson & Malthotra, January 14, 1999, "Final Additional Site Characterization Report" for the Tar Creek NPL Site, prepared for the U.S. Department of Interior, Bureau of Land Management, BLM Oklahoma City Field Area, Table 5.3.1-1.
3) United States Environmental Protection Agency (EPA), 1992 "Guidance for Data Usability in Risk Assessment (Part A)."

Conclusions

1. The data confirm chat piles contain high concentrations of lead, cadmium, and zinc relative to background and high concentrations of lead relative to human health risk levels. The lead and zinc concentrations are much higher than the cadmium values.

2. Total lead, cadmium, and zinc concentrations increase with decreasing particle size of chat material. Higher lead concentrations are observed with decreasing particle size of chat especially below the #40 sieve size (0.425 mm).

3. The data indicate that more than half the total lead mass is concentrated in the small size fractions (< 0.425 mm) of a chat pile, but the amount of chat represented by this fine material is only 15 to 25 per cent of the total chat pile volume, by weight.

4. The data indicate that there is a large variation in lead, cadmium, and zinc concentrations between different chat piles and less variably within a single chat pile, while sieve analyses show fairly consistent particle size distribution (gradation) throughout. Each chat pile will require sampling and analysis to determine the average lead, cadmium, and zinc content and variability of a chat pile.

5. Average Pb, Cd, and Zn concentrations of a chat pile may be characterized with as few as 10 samples independently of volume or area. The number of samples required may be specific to each chat pile. Average metal concentrations are not appropriate for determining a safe use of the chat.

6. A raw chat sample that tests below 500 mg/kg lead, contains up to 22 % fine sized particles. These fines that represent the higher concentrations will test in excess of 500 mg/kg lead.

7. The sieve analyses data shows that the #40 sieve (0.425 mm) represents a break point where the concentration of lead begin to rise greatly for those particles that pass this sieve size. The percentage of chat volume that is less than 0.425 mm ranges from 15 to 25 percent by weight.

8. Separation of chat by washing and /or dry sieving will produce chat piles of large particle sizes containing about 80% of the original volume but with much reduced lead concentrations.

9. The lead mass data show that while high concentrations of lead are in the fine-sized particles, the bulk of the chat (80%) greater than the #40 sieve contains between 13 and 48 percent of the lead and displays very low concentrations. The data does not show whether this lead is vulnerable to weathering or abrasion, i.e., generating additional fine-sized particles with high lead concentration.

10. There is a good correlation for total lead, cadmium, and zinc concentrations between the inductively coupled plasma (ICP) method and laboratory X-ray Fluorescence (XRF) method of analyses for chat samples. Therefore, both methods are acceptable for analyzing the chat. Note that a laboratory XRF machine was used with moisture and particle size controls. A handheld XRF machine may not correlate as well with ICP data and may not be acceptable.

Recommendations

- Chat with particle sizes larger that the # 40 sieve size (> 0.425 mm) may be acceptable for many different uses but would require separation from the fines. The chat particles between the #200 sieve (0.075 mm) and #40 sieve (0.425 mm) may be acceptable in industrial or commercial uses. The chat material that passes the #200 (0.075 mm) sieve may have very limited uses, due to high lead content. The use of chat in any form in residential properties is not recommended.

- The effect of the fine-sized particles upon the total lead content of raw chat should be assessed further. This determination is needed regardless of mixing the chat with other road building materials to offset high lead concentrations. This may not reduce the risk of exposure to lead unless the concentration in the fines is also reduced or the material is permanently encapsulated.

- To determine risk from chat, raw chat should be sieved prior to analyses for comparison to an action level. Sampling protocols for chat will differ from those for soil.

- The fine-sized particles may increase human exposure to lead cadmium, and zinc via inhalation and absorption. To reduce risk from chat piles, engineering controls, such as wetting, surfactants, and vegetation, should be tested and implemented to reduce release of fine-sized particles.

- Acceptable uses of chat are those that minimize or eliminate exposure to lead, cadmium, and zinc, especially the exposure to the fine-sized particles. This may be accomplished by encapsulation of raw chat or mechanical separation and discarding the fine-sized particles.

- Testing chat piles prior to reuse will help to ensure that the intended purpose is appropriate.

Further Needs

- The effect of placing chat into the underground mine workings (subaqueous disposal) needs to be studied in relation to the possible increase in the total lead, cadmium, and zinc concentrations in the mine water (ground water) and subsequent effects on surface water. Studies in Missouri by the potentially responsible parties (PRPs) have been conducted to determine the effect of zinc on subaqueous disposal of chat. Studies specific to chat in Oklahoma are required based on the chemistry of the water. The effect of other metals should also be studied.

- The use of whole or raw chat (large particles to fine particles) in asphalt, concrete, epoxy coatings, and other encapsulation technologies needs to be studied. Encapsulation of chat, especially the fine–sized particles, would minimize and mitigate exposure to lead. Studies are needed to determine whether increased percentages of raw chat used in these encapsulated forms are structurally and environmentally sound and durable.

- Exposure to lead in soil is different than exposure to raw chat, especially considering the concentration of lead in fine-sized chat particles and the increase potential of exposure to fine-sized particles. EPA's human health risk levels used in EPA Region 6 and in Oklahoma are based on metals in soil. A determination is needed of acceptable risk levels for the metals in chat and the corresponding appropriate uses for chat.

- The feasibility and protectiveness of raw chat as a base, sub-base, and/or subgrade in roadways needs to be investigated. Use of raw chat in these forms could accelerate the consumption of chat and help alleviate exposure to chat. Studies should be designed to determine whether these uses of raw chat are structurally and environmentally sound.

- The total metal concentration of large particles is very small. Evaluation of weathering and abrasion characteristics of large chat particles should be studied relative to the production of fine-sized particles and resultant concentration of metals in the fine material.

- Tailing or mill ponds located on the site resulted from historical ore processing. Current practices of washing chat generate wastewater containing very fine material (high total suspended solids) with high metals concentrations that is discarded in these old tailings ponds. If mechanical separation is determined to be a safe and feasible way to re-use chat, then the characterization, disposal, and final disposition of the contaminants are needed. Risks from a high concentration of fine-sized particles are currently unknown. Testing of these mill ponds to determine total lead, cadmium, and zinc concentrations is needed to quantify risk, evaluate disposal and management options for washing operations, and to determine the appropriate remedy.

REFERENCES

1. Brown and Root Environmental, July, 1995, "Sampling and Analysis Plan Mining Waste Remedial Investigation/Feasibility Study Tar Creek Superfund Site, Ottawa County, Oklahoma." Prepared for the US Army Corps of Engineers Tulsa District and U.S. Environmental Protection Agency Region VI.

2. C. C. Johnson and Malthotra, January 14, 1999, "Final Additional Site Characterization Report" for the Tar Creek NPL Site, prepared for the U.S. Department of Interior, Bureau of Land Management, BLM Oklahoma City Field Area.

3. Dames and Moore, January 27, 1993, "Final Remedial Investigation for Cherokee County, Kansas, CERCLA Site Baxter Springs/Treece Subsites" Volume I and II.

4. _____, October 31, 1995, "Final Remedial Investigation Neck/ALBA, Snap, Oronogo/Duenweg, Joplin, Thoms, Carl Junction, and Waco Designated Areas, Jasper County Site, Jasper County, Missouri" Volumes I and II.

5. Ecology and Environment, Inc., June 1996a, "Supplement to the Site Assessment Report, Residential Soil, Tar Creek Superfund Site, Statistical Correlations between the ICP and XRF Data and AA and XRF Data," Prepared for the U.S. Environmental Protection Agency Region 6.

6. _____, August 1996b, "Baseline Human Health Risk Assessment of Residential Exposures Tar Creek Superfund Site, Ottawa County, Oklahoma," Prepared for the U.S. Environmental Protection Agency Region 6.

7. Gary, Margaret, Jr. McAfee Robert, and Wolf, Carol L., 1977 "Glossary of Geology", American Geological Institute (AGI), Washington, D.C.

8. Isern, Elmer, November 1943, "Central Mill", Eng and Mining J, 144 (11), 93-101.

9. Oklahoma Department of Environmental Quality (DEQ), May 2000, "Summary Report of Washed and Unwashed Mine Tailings (Chat) from the Tar Creek Superfund Site Area."

10. U. S. Army Corps of Engineers (CORPS), 2000, Tulsa District, Tulsa, Oklahoma, Chat volumes from fly over for the Tar Creek Superfund Site, Ottawa County, Oklahoma."

11. United States Environmental Protection Agency (EPA), 1992 "Guidance for Data Usability in Risk Assessment (Part A)."

12. _____, August 1997, Region 6, "Record of Decision for Residential Areas Operable Unit 2" for the Tar Creek Superfund Site, Ottawa County, Oklahoma.

13. _____, 2000, Region 6, "Human Health Media-Specific Screening Levels."

APPENDIX A

CHAT USAGE GUIDELINES

MINE TAILINGS USAGE GUIDELINES FOR RESIDENTIAL PROPERTIES

By the Oklahoma Department of Environmental Quality (DEQ)

These guidelines explain what the DEQ considers to be inappropriate uses of mine tailings, in particular, chat and mill-pond sand, from the lead and zinc mines of Ottawa County, Oklahoma. Mine tailings from other portions of the tri-state mining area, which extends into Kansas and Missouri, are included if they are used in the State of Oklahoma. Although mine tailings are a significant economic resource to the area, these materials can also pose a significant health risk to the residents, especially the children of Ottawa County, due to the high lead content. In order to minimize the health risks from lead exposure, people should not play on the chat piles or former mill-ponds. The mine tailings must be handled and used only in ways that do not increase the chances of exposure. The mine tailings are also high in sulfur, which can corrode metal that is left in contact with them. Users and sellers of the mine tailings should be aware that they may be liable for cleanup costs and fines for inappropriate usage.

Inappropriate Use of Mine Tailings for Residential Properties:

- Use as fill material on residential properties
- Use as base, surface material, or ground cover under playground equipment
- Use in residential driveways
- Use as gravel or unencapsulated surface material in parking lots, alleyways, or roadways
- Use in public areas such as parks, schools, or playgrounds where children are likely to be exposed
- Use as sandblasting material where soil in residential areas may be contaminated by its use
- Use as replacement for clean gravel or sand under homes, in sewer lines, in ditches or other areas where children may be exposed either directly or indirectly
- Use as fill in slab foundations

NOTE: For purposes of these guidelines, residential properties are defined as places where people live such as single dwelling homes, apartments, mobile home parks, retirement homes, daycare centers, etc. Also included are public areas such as parks, schools, or playgrounds. "Residential properties" does not include residential streets, county roads, or highways.

RESPONSIBILITY FOR INAPPROPRIATE USES OF MINE TAILINGS

Persons or business who knowingly buy, sell, haul, or otherwise use mine tailings for inappropriate purposes may be held responsible either to perform the cleanup or to pay the costs of cleanup of contaminated areas. After June 1, 2000, the ODEQ may issue cleanup orders to persons or businesses that use mine tailings inappropriately. Residential properties which have been cleaned up by EPA and which have had mine tailings hauled back on to the property before June 1, 2000 will also be subject to the cleanup orders. In addition to responsibility for cleanup of contaminated areas, persons or businesses to which a cleanup order is issued may be subject to fines of up to $10,000 per day.

To report inappropriate use of mine tailings or for answers to any questions or concerns:

- Call DEQ Customer Assistance toll free at 1-800-869-1400
- Provide the location of the material
- Provide the name of the responsible party
- The approximate quantity if known

We appreciate your cooperation and continued support of our efforts in Ottawa County.

APPENDIX B

STATISTICAL EQUATIONS (EPA 1992)

Equation 1: $n \geq [(Z_\alpha + Z_\beta)/D]^2 + 0.5Z_\alpha{}^2$

Where:

n	=	required number of samples
Z_α	=	percentile of the standard normal distribution such that $P(Z \geq Z_\alpha) = \alpha$
Z_β	=	percentile of the standard normal distribution such that $P(Z \geq Z_\beta) = \beta$
D	=	(minimum relative detectable difference)/CV
CV	=	coefficient of variation = s/x
s	=	standard deviation
x	=	mean

Using the following statistical values:

Confidence level = 80%
Power = 90%
Minimum relative detectable difference = 20%

Therefore:

Z_α = 0.842
Z_β = 1.282
D = 0.2

Using these values, the above equation for n is reduced to:

Equation 2: $n \geq 112.8\ (CV)^2 + 0.354$

APPENDIX C

DATA TABLES

TABLE 1. WHOLE CHAT SAMPLES - TOTAL METAL CONTENT (mg/kg)							
KENOYER NORTH CHAT PILE							
TAR CREEK SUPERFUND SITE							
Sampled by the Oklahoma Department of Environmental Quality on July 19, 2000.							
Sample ID	**Lead**	**Cadmium**	**Zinc**				
	(mg/kg)	(mg/kg)	(mg/kg)				
01KNRC-A1	1,028	35	16,548				
01KNRC-B1	976	35	15,708				
01KNRC-C1	1,010	36	15,382				
01KNRC-D1	1,011	41	16,581				
01KNRC-F1	890	36	14,531				
02KNRC-A1	1,781	71	29,304				
02KNRC-B1	1,775	67	34,407				
02KNRC-C1	1,551	65	28,256				
02KNRC-D1	1,264	57	22,024				
03KNRC-A1	631	17	11,251				
03KNRC-B1	716	22	13,987				
03KNRC-C1	657	20	11,505				
03KNRC-D1	736	30	13,723				
03KNRC-F1	715	24	13,192				
04KNRC-A1	1,261	29	18,492				
04KNRC-B1	1,379	29	15,335				
04KNRC-C1	1,542	27	12,844				
04KNRC-D1	1,561	26	14,379				
05KNRC-A1	985	36	17,647				
05KNRC-B1	1,286	26	20,698				
05KNRC-C1	1,152	35	16,406				
05KNRC-D1	1,391	33	19,857				
06KNRC-A1	1,541	29	18,246				
06KNRC-B1	1,653	29	20,403				
06KNRC-C1	1,618	28	19,863				
06KNRC-D1	1,370	35	19,326				
06KNRC-F1	1,663	28	19,971				
07KNRC-A1	1,296	25	13,389				
07KNRC-B1	1,237	28	13,032				
07KNRC-C1	1,162	25	12,629				
07KNRC-D1	1,118	35	13,825				
08KNRC-A1	1,166	21	14,061				
08KNRC-B1	1,113	17	16,471				
08KNRC-C1	1,157	24	19,358				
08KNRC-D1	1,286	26	20,463				
08KNRC-F1	1,304	22	18,190				

TABLE 1. WHOLE CHAT SAMPLES - TOTAL METAL CONTENT (mg/kg)							
KENOYER NORTH CHAT PILE							
TAR CREEK SUPERFUND SITE							
Sampled by the Oklahoma Department of Environmental Quality on July 19, 2000.							
Sample ID	**Lead**	**Cadmium**	**Zinc**				
	(mg/kg)	(mg/kg)	(mg/kg)				
09KNRC-A1	1,039	24	15,964				
09KNRC-B1	926	16	14,917				
09KNRC-C1	1,014	19	16,565				
09KNRC-D1	1,034	23	16,100				
10KNRC-A1	1,286	23	11,138				
10KNRC-B1	1,569	22	13,966				
10KNRC-C1	1,710	20	14,245				
10KNRC-D1	1,603	21	14,709				
11KNRC-A1	2,121	48	15,458				
11KNRC-B1	1,911	46	16,051				
11KNRC-C1	1,852	38	14,236				
11KNRC-D1	2,207	44	16,644				
11KNRC-F1	2,123	54	16,624				
mean	1,314	32	16,896				
n	49	49	49				
stan dev	389	13	4,475				
min	631	16	11,138				
max	2,207	71	34,407				
median	1,286	28	16,051				
CV	0.296	0.407	0.265				
recalculated n	10	19	8				
volume (yds3)	1,201,221						
NOTES:	F1 = DUPLICATES						
	SAMPLE WAS A 5-PART COMPOSITE USING A FRONT END LOADER						
	FRONT END LOADER WAS DIVIDED INTO 4 SECTIONS						
	PILE DIVIDED INTO 11 SECTIONS						
	SAMPLES WERE ANALYZED ON A QUANTUM XRF						

TABLE 2. WHOLE CHAT SAMPLES - TOTAL METAL CONTENT (mg/kg)						
KENOYER SOUTH CHAT PILE						
TAR CREEK SUPERFUND SITE						
Sampled by the Oklahoma Department of Environmental Quality on July 19, 2000.						
Sample ID	**Lead**	**Cadmium**	**Zinc**			
	(mg/kg)	(mg/kg)	(mg/kg)			
01KN2RC-A	262	65	14,647			
01KN2RC-B	271	71	16,131			
01KN2RC-C	263	73	16,026			
01KN2RC-D	282	69	17,137			
01KN2RC-F	258	68	15,646			
02KN2RC-A	264	84	15,433			
02KN2RC-B	393	96	23,247			
02KN2RC-C	332	81	18,457			
02KN2RC-D	442	88	20,894			
03KN2RC-A	362	32	17,065			
03KN2RC-B	351	34	13,898			
03KN2RC-C	475	49	14,757			
03KN2RC-D	563	37	19,461			
03KN2RC-F	407	39	16,806			
mean	352	63	17,115			
n	14	14	14			
stan dev	95	21	2,608			
min	258	32	13,898			
max	563	96	23,247			
median	342	69	16,469			
CV	0.270	0.338	0.152			
recalculated n	9	13	3			
volume (yds3)	29,342					
NOTES:	F = DUPLICATES					
	SAMPLE WAS A 5-PART COMPOSITE USING A FRONT END LOADER					
	FRONT END LOADER WAS DIVIDED INTO 4 SECTIONS					
	PILE DIVIDED INTO 3 SECTIONS					
	SAMPLES WERE ANALYZED ON A QUANTUM XRF					

TABLE 3. WHOLE AND SIEVE CHAT SAMPLES					
TOTAL METAL CONTENT (mg/kg)					
BAXTER SPRINGS/TREECE KANSAS CHAT PILES					
TAR CREEK SUPERFUND SITE					
Data from the Cherokee County, Kansas, and Jasper County, Missouri					
Remedial Investigations (RI), Brown & Root (1995)					
Sample ID	**Lead**	**Cadmium**	**Zinc**		
	(mg/kg)	(mg/kg)	(mg/kg)		
BX-1	200	20	4,800		
BC-2	700	32	4,800		
BX-2	1,600	46	13,000		
BC-4	310	23	5,200		
BC-11	770	13	3,100		
BC-12	270	47	8,500		
BC-20	930	23	5,000		
TX-4	1,700	89	13,000		
TX-5	420	32	6,500		
TC-15	670	25	4,700		
TC-16	340	56	9,400		
TC-20	120	92	13,000		
TC-23	1,100	31	6,700		
TC-40	1,400	63	11,000		
TC-42	100	61	9,400		
TC-59	1,300	61	11,000		
mean	746	45	8,069		
n	16	16	16		
stan dev	538	24	3,399		
min	100	13	3,100		
max	1,700	92	13,000		
median	685	39	7,600		
CV	0.721	0.538	0.421		
recalculate n	59	33	20		

TABLE 4. WHOLE AND SIEVE CHAT SAMPLES					
TOTAL METAL CONTENT (mg/kg)					
JOPLIN MISSOURI CHAT					
TAR CREEK SUPERFUND SITE					
Data from the Cherokee County, Kansas, and Jasper County, Missouri					
Remedial Investigations (RI), Brown & Root (1995)					
Sample ID	**Lead**	**Cadmium**	**Zinc**		
	(mg/kg)	(mg/kg)	(mg/kg)		
JC-2	610	92.8	14,000		
JC-3	458	53.3	6,380		
JC-4	270	28.7	6,190		
JC-7	190	53.1	12,500		
JC-7 (+20)	352	52.1	13,200		
JC-7 (+200)	126	69.7	14,000		
JC-7 (+4)	186	70.1	18,900		
JC-7 (-200)	430	124.0	39,200		
JC-8	1,020	88.1	11,500		
JC-9	426	68.0	12,500		
JC-10	215	54.5	7,370		
JC-11	339	93.3	20,800		
JC-12	159	42.1	7,130		
JC-12 (+20)	261	30.6	5,140		
JC-12 (+200)	413	50.4	11,700		
JC-12 (+4)	231	45.5	7,290		
JC-12 (-200)	3,800	110.0	23,100		
JC-13	169	36.7	6,180		
JC-14	280	38.6	6,450		
JC-15	278	40.1	6,880		
JC-16	116	26.9	5,510		
JC-17	132	42.6	7,520		
JSUB-1C0-0.5	382	159.0	22,700		
JSUB-1C075-1.25	570	103.0	15,300		
mean	476	66	12,560		
n	**24**	**24**	**24**		
stan dev	**894**	**37**	**6,219**		
min	116	27	5,140		
max	3,800	159	39,200		
median	279	53	11,600		
CV	1.881	0.559	0.495		
recalculate n	399	36	28		

TABLE 5. WHOLE AND SIEVE CHAT SAMPLES					
TOTAL METAL CONTENT (mg/kg)					
ORONOGO/DUENWEG MISSOURI CHAT PILES					
TAR CREEK SUPERFUND SITE					
Data from the Cherokee County, Kansas, and Jasper County, Missouri					
Remedial Investigations (RI), Brown & Root (1995)					
Sample ID	**Lead**	**Cadmium**	**Zinc**		
	(mg/kg)	(mg/kg)	(mg/kg)		
OC-1	304	40.0	4,780		
OC-2	414	9.2	2,740		
OC-3	1,300	12.3	1,520		
OC-4	214	7.5	632		
OC-5	328	152.0	27,500		
OC-8	940	74.3	26,900		
OC-7	1,180	6.5	882		
OC-8	298	24.1	3,250		
OC-9	412	57.4	10,300		
OC-10	456	140.0	23,900		
OC-11	203	45.8	5,860		
OC-12	1,920	17.8	2,100		
OC-13	233	15.2	1,590		
OC-15	2,310	27.3	3,580		
OC-16	540	40.0	4,910		
OC-17	2,110	7.3	1,130		
OC-18	2,220	27.0	4,500		
OC-19	358	41.8	600		
OC-20	72	12.0	1,480		
OC-21	600	41.1	6,160		
OC-21(+20)	115	15.3	1,970		
OC-21(+200)	191	55.7	7,510		
OC-21(+4)	55	6.6	968		
OC-21(-200)	1,990	31.8	3,120		
OC-22	2,400	44.5	8,040		
OC-23	443	18.7	1,060		
OC-24	431	85.8	16,900		
OC-25	820	31.4	3,430		
OC-27	800	27.8	5,170		
OC-28	500	40.8	5,260		
OC-29	2,600	152.0	28,100		
OC-30	730	135.0	14,500		
OC-31	1,410	75.3	12,200		
OC-32	137	119.0	12,900		
OC-33	500	35.4	5,620		
OC-34	320	3.7	468		
OC-35	2,400	56.3	11,300		
OC-38	8,000	149.0	37,200		
OC-38 (+20)	357	66.2	10,700		
OC-38 (+200)	1,240	111.0	18,800		
OC-38 (+4)	258	61.9	9,530		
OC-38 (-200)	4,370	234.0	40,700		

TABLE 5. WHOLE AND SIEVE CHAT SAMPLES					
TOTAL METAL CONTENT (mg/kg)					
ORONOGO/DUENWEG MISSOURI CHAT PILES					
TAR CREEK SUPERFUND SITE					
Data from the Cherokee County, Kansas, and Jasper County, Missouri					
Remedial Investigations (RI), Brown & Root (1995)					
Sample ID	**Lead**	**Cadmium**	**Zinc**		
	(mg/kg)	(mg/kg)	(mg/kg)		
OC-37	1,090	83.2	15,300		
OC-39	237	133.0	19,800		
OC-40	334	24.9	2,910		
OC-41	472	29.0	4,090		
OC-42	183	27.5	3,650		
OC-43	348	74.4	15,000		
OC-44	106	10.7	1,640		
OC-45	800	50.6	6,590		
OC-47	428	53.0	9,380		
OC-48	277	23.2	3,250		
OC-49	730	91.0	13,800		
OC-50	1,400	36.5	6,740		
OC-53	1,620	6.0	1,020		
OC-54	1,100	45.0	5,280		
OSUB-7C0-0.5	310	48.0	74,700		
OSUB-7C0-0.6	420	101.0	59,900		
mean	971	55	10,911		
n	**58**	**58**	**58**		
stan dev	**1,260.88**	**47.90**	**14,183.56**		
min	55	4	468		
max	8,000	234	74,700		
median	464	41	5,450		
CV	1.298	0.870	1.300		
recalculate n	190	86	191		

TABLE 6. CHAT SAMPLES - TOTAL LEAD RESULTS (mg/kg or ppm)						
THE BUREAU OF LAND MANAGEMENT (CCJM 1999)						
SAMPLE	<250 u	250u - 1mm	1 -2 mm	2 - 4.75 mm	> 4.75 mm	Whole Chat*
TC-C-1-1A	4,670	654	1,070	132	105	676
TC-C-1-2A	11,700	1,310	768	476	371	2,192
TC-C-1-3A	2,360	701	1,470	3,620	200	2,289
TC-C-2-A1	2,200	748	245	3,670	200	1,764
TC-C-2A	435	253	198	4,610	130	1,274
TC-C-3-1A	1,410	400	252	265	198	293
TC-C-4-1A	779	274	168	2,280	na	1,146
TC-C-5-1A	4,960	2,120	481	218	183	957
TC-C-6-1A	335	124	55	41	125	88
TC-C-7-1A	3,640	641	270	244	49	813
TC-C-8-1A	2,920	600	325	3,130	187	1,596
TC-C-8-2A	2,840	804	446	144	156	615
TC-C-10-1A	454	109	50	34	19	181
TC-C-9A	856	302	183	57	38	252
TC-C-10-2A	442	108	97	75	75	78
TC-C-11-1A	1,050	372	157	155	62	300
TC-C-11-2A	2,200	458	327	117	507	454
TC-C-11-3A	1,950	635	375	130	44	503
TC-C-11-4A	4,230	400	285	221	100	930
TC-C-11-5A	2,750	674	303	177	218	712
TC-C-12-1A	6,560	1,970	2,480	345	333	1,421
TC-C-13-1A	7,110	1,960	1,300	273	100	1,519
TC-C-14A	5,780	1,480	1,120	406	566	1,467
TC-C-15-1A	1,280	326	926	165	195	524
TC-C-15-2A	2,270	600	461	182	82	809
TC-C-15-3A	1,770	613	491	194	146	478
TC-C-15-4A	952	573	258	114	29	362
TC-C-15-5A	1,820	638	331	180	44	396
TC-C-15-6A	1,540	323	215	170	151	144
TC-C-16-1A	2,570	567	314	174	26	662
MEAN	2,794	691	514	733	160	830
MEDIAN	2,200	600	325	182	138	676
MINIMUM	335	108	50	34	19	78
MAXIMUM	11,700	2,120	2,480	4,610	566	2,289
STD. ERROR						
STD. DEV.	2,482	541	525	1,284	136	613

TABLE 7. WHOLE CHAT SAMPLES - TOTAL METAL CONTENT (mg/kg)						
RIVER ROCK/FLY ASH MIXTURE KENOYER NORTH CHAT PILE						
TAR CREEK SUPERFUND SITE						
Sampled by the Oklahoma Department of Environmental Quality on July 19, 2000.						
Sample ID	**MIXTURE**	**Lead**	**Cadmium**	**Zinc**		
		(mg/kg)	(mg/kg)	(mg/kg)		
01KNMRRFA-A	River Rock/Fly Ash	1,107	25	12,992		
01KNMRRFA-B	River Rock/Fly Ash	1,078	18	11,249		
01KNMRRFA-C	River Rock/Fly Ash	1,018	24	11,995		
01KNMRRFA-D	River Rock/Fly Ash	1,025	22	13,219		
01KNMRRFA-F	River Rock/Fly Ash	1,038	17	11,417		
02KNMRRFA-A	River Rock/Fly Ash	663	12	7,863		
02KNMRRFA-B	River Rock/Fly Ash	521	9	5,162		
02KNMRRFA-C	River Rock/Fly Ash	378	8	3,270		
02KNMRRFA-D	River Rock/Fly Ash	518	8	5,857		
03KNMRRFA-A	River Rock/Fly Ash	731	22	13,915		
03KNMRRFA-B	River Rock/Fly Ash	872	30	16,601		
03KNMRRFA-C	River Rock/Fly Ash	1,052	32	16,252		
03KNMRRFA-D	River Rock/Fly Ash	1,160	24	15,114		
03KNMRRFA-F	River Rock/Fly Ash	1,046	35	19,320		
mean		872	20	11,730		
n		14	14	14		
stan dev		259	9	4,693		
min		378	8	3,270		
max		1,160	35	19,320		
median		1,022	22	12,494		
CV		0.297	0.433	0.400		
NOTES:	F1 = DUPLICATES					
	SAMPLE WAS A 5-PART COMPOSITE USING A FRONT END LOADER					

TABLE 8. WHOLE CHAT SAMPLES - TOTAL METAL CONTENT (mg/kg)							
CLAY MIXTURE KENOYER NORTH CHAT PILE							
TAR CREEK SUPERFUND SITE							
Sampled by the Oklahoma Department of Environmental Quality on July 19, 2000.							
Sample ID	**MIXTURE**	**Lead**	**Cadmium**	**Zinc**			
		(mg/kg)	(mg/kg)	(mg/kg)			
01KNMCLAY-	Clay	526	14	7,923			
01KNMCLAY-	Clay	430	8	6,151			
01KNMCLAY-	Clay	643	21	11,138			
01KNMCLAY-	Clay	640	16	12,285			
01KNMCLAY-	Clay	475	15	6,970			
02KNMCLAY-	Clay	689	18	10,776			
02KNMCLAY-	Clay	682	16	11,008			
02KNMCLAY-	Clay	1,006	22	17,174			
02KNMCLAY-	Clay	1,067	27	16,501			
03KNMCLAY-	Clay	533	25	9,995			
03KNMCLAY-	Clay	523	22	8,938			
03KNMCLAY-	Clay	506	25	9,581			
03KNMCLAY-	Clay	499	22	8,798			
03KNMCLAY-	Clay	476	22	8,869			
mean		621	20	10,436			
n		14	14	14			
stan dev		194	5	3,181			
min		430	8	6,151			
max		1,067	27	17,174			
median		530	22	9,788			
CV		0.312	0.267	0.305			
NOTES:	F1 = DUPLICATES						
	SAMPLE WAS A 5-PART COMPOSITE USING A FRONT END LOADER						

TABLE 9. WHOLE CHAT SAMPLES - TOTAL METAL CONTENT (mg/kg)						
FLY ASH KENOYER NORTH CHAT PILE						
TAR CREEK SUPERFUND SITE						
Sampled by the Oklahoma Department of Environmental Quality on July 19, 2000.						
Sample ID	**MIXTURE**	**Lead**	**Cadmium**	**Zinc**		
		(mg/kg)	(mg/kg)	(mg/kg)		
01KNFA-A	Fly Ash	223	3	366		
01KNFA-B	Fly Ash	228	3	401		
01KNFA-C	Fly Ash	209	3	370		
01KNFA-D	Fly Ash	227	3	411		
01KNFA-F	Fly Ash	222	3	383		
mean		221.80	2.60	386.20		
n		**5**	**5**	**5**		
stan dev		**7.60**	**0.22**	**19.46**		
min		209	3	366		
max		228	3	411		
median		223	3	383		
CV		0.034	0.086	0.050		
NOTES:	F1 = DUPLICATES					
	SAMPLE WAS A 5-PART COMPOSITE USING A FRONT END LOADER					

TABLE 10. WHOLE CHAT SAMPLES - TOTAL METAL CONTENT (mg/kg)					
ROADS IN TAR CREEK					
TAR CREEK SUPERFUND SITE					
Sampled by the Oklahoma Department of Environmental Quality on September 6, 2000.					
Sample ID	**ROAD NAME**	**Lead**	**Cadmium**	**Zinc**	
		(mg/kg)	(mg/kg)	(mg/kg)	
DOUTH-M	Douthat Road (Bridge)	555	41	7,498	
DOUTH-E	Douthat Road (East of bridge 1000 ft)	287	28	4,894	
DOUTH-W	Douthat Road (West of bridge 1000 ft)	229	31	5,214	
S590INT-1	South 590 INT East 30 WEST	133	14	2,572	
S590INT-2	South 590 INT East 30 WEST	151	15	2,814	
S590N-3	South 590 North 1000 ft	118	15	3,092	
S590N-4	South 590 South 1000 ft	136	22	3,830	
E30WTHOM-1	East 30 West	504	38	8,368	
E30WTHOM-2	East 30 West	401	19	5,596	
mean		279	25	4,875	
n		9	9	9	
stan dev		169	10	2,048	
min		118	14	2,572	
max		555	41	8,368	
median		229	22	4,894	
CV		0.605	0.412	0.420	
NOTES:	E30THOM-2 = DUPLICATE				
	SAMPLE WAS A 3-PART COMPOSITE				
	FROM EACH SIDE AND MIDDLE OF ROAD				

TABLE 11. SIEVED CHAT SAMPLES - TOTAL METAL CONTENT (mg/kg)

TAR CREEK SUPERFUND SITE

Sampled by the Oklahoma Department of Environmental Quality on November 23, 1999 and July 19, 2000.

SIEVE SIZE/NUMBER	KNRC-01 LEAD	KNRC-06 LEAD	ATRC LEAD	OTRC LEAD
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
4	68	85	25	70
10	286	352	47	238
40	371	413	225	319
80	700	1136	324	884
200	1719	2968	671	2704
PAN	3146	7068	1789	6668

SIEVE SIZE/NUMBER	KNRC-01 CADMIUM	KNRC-06 CADMIUM	ATRC CADMIUM	OTRC CADMIUM
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
4	3	1	ND	2
10	39	28	7	303
40	17	51	37	25
80	69	70	61	54
200	96	70	82	100
PAN	93	71	128	170

SIEVE SIZE/NUMBER	KNRC-01 ZINC	KNRC-06 ZINC	ATRC ZINC	OTRC ZINC
	(mg/kg)	(mg/kg)	(mg/kg)	(mg/kg)
4	606	219	251	260
10	8,128	6,036	2,738	47,940
40	3,884	9,100	4,206	4,580
80	14,810	20,120	11,110	9,738
200	27,900	33,640	14,772	20,340
PAN	39560	54,260	24840	39,780

TABLE 11. SIEVED CHAT SAMPLES - PARTICLE SIZES

TAR CREEK SUPERFUND SITE

Sampled by the Oklahoma Department of Environmental Quality on November 23, 1999 and July 19, 2000.

SIEVE SIZE/NUMBER	SIEVE SIZE/NUMBER	KNRC-01 % PASSING	KNRC-06 % PASSING	ATRC % PASSING	OTRC % PASSING
1/2 INCH	0.500 inch (12.70 mm)	100.0	100	100.0	100
3/8 INCH	0.375 inch (9.53 mm)	99.8	100	99.9	99.9
4	0.187 inch (4.75 mm)	86.1	80.3	80.4	82.0
10	0.079 inch (2.00 mm)	65.4	43.1	52.7	50.1
40	0.017 inch (420 um)	17.3	15.8	22.6	18.7
80	0.007 inch (177 um)	8.6	7.7	14.3	10.3
200	0.003 inch (75 um)	3.9	3.1	7.4	5.6
PAN					

TABLE 11. SIEVED CHAT SAMPLES - PARTICLE SIZES AND TOTAL LEAD CONTENT

THE BUREAU OF LAND MANAGEMENT (CCJM 19990)

TAR CREEK SUPERFUND SITE

SIEVE SIZE/NUMBER	BLM % PASSING			BLM LEAD
				(mg/kg)
3/8 INCH	100.0			
4	78.3	21.7	(>4.75 mm)	160
9	45.2	33.1	(2.00 - 4.75 mm)	733
16	29.8	15.4	(1 - 2 mm)	514
60	12.9	16.9	(250 um - 1 mm)	691
PAN		13.2	(<250 um)	2,794