STATE OF OKLAHOMA

DEPARTMENT OF ENVIRONMENTAL QUALITY
(DEQ)
CUSTOMER SERVICES DIVISION

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Fish Tissue Metals Analysis in the Tri-State Mining Area

FY 2003

Final Report

Submitted by:

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Executive Summary

The Customer Services Division (CSD) of the Oklahoma Department of Environmental Quality (ODEQ) performed a study to determine the safety of consuming fish caught in Oklahoma waters affected by runoff from the Tri-State Mining Area and the Tar Creek Superfund Site. Responding to concerns by local residents and tribes, this study was designed to determine levels of metals in fish tissue that would be harmful to human health if consumed in excess amounts. Local tribes from the Tar Creek area indicated traditional customs involve eating whole fish, including bones, which have been canned by means of pressure-cooking. Since metals are known to accumulate in the bones and organs of fish, there was a concern that these traditional methods of preparation would be unsafe. Local tribes advised ODEQ they believed fish consumption rates were higher among tribal members than among the general public.

CSD field personnel worked cooperatively with the US Fish and Wildlife Service to collect fish from the Neosho and Spring Rivers and local ponds receiving mine waste runoff. The State Environmental Laboratory developed sample preparation and analysis methods specifically for this study. CSD risk assessment personnel used EPA guidance to develop safe levels for cadmium and zinc in fish, and utilized the Integrated Exposure Uptake Biokinetic (IEUBK) Model for evaluating lead concentrations in fish that would be safe for the public to consume.

Results of this study conclude that fillets of fish caught in ponds within the Tar Creek Superfund Site and the Spring and Neosho Rivers are safe to eat at rates up to 6 8-ounce meals per month based on laboratory reporting limits. Whole-uneviscerated and whole-eviscerated portions of all fish from the Oklahoma sections of the Spring and Neosho Rivers downstream to Grand Lake and ponds in the Tri-State Mining Area should not be consumed. Fish from these waters have higher concentrations of lead than fish collected in a national study. The higher fish tissue lead concentrations are positively correlated (R^2 = 86%) to lead concentrations in the sediments of the area waters.

A follow-up study is recommended to verify these results and to determine the downstream extent of problems. Future studies should incorporate lower analytical reporting limits.

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Background and Statement of Issues

The Tri-State Mining District located in northeast Oklahoma, southeast Kansas, and southwest Missouri was once a major provider of lead and zinc ores in the early to mid 20^{th} century. Since the cessation of mining in the area, the mines remain closed and abandoned. Metals located both in the mines and in waste ore on the surface can become mobilized under low pH conditions and be transported by ground and surface waters. Water has been discharging from the closed mines since the 1970's and is a major source of contamination to Tar Creek, a tributary of the Neosho River.

The Spring and Neosho Rivers and their tributaries (particularly Tar Creek) have been impacted by runoff from these abandoned lead and zinc mines. Additionally, the percolation of rainwater through chat piles mobilizes metals into solution, which flows into local ponds, many of which are millponds at abandoned ore processing sites. Fish caught locally in these rivers and ponds constitute a significant portion of the diets of the citizens of the area. Furthermore, area tribal members report that fish are prepared and consumed using a pressure cooker to can and preserve whole fish including bones. These methods would potentially increase the ingestion of metals that might accumulate in fish. Additionally, local tribes advised that they believed fish consumption rates were higher among tribal members than the general public. Questions have been raised about the safety of eating fish from these waters.

The consumption of fish containing elevated levels of metals is a concern because chronic exposure to heavy metals can cause health problems. Chronic lead exposure has been linked to anemia, neurological dysfunction and renal impairment. Chronic cadmium exposure has been linked to renal damage, hypertension, and cardiovascular effects. Although zinc is an essential nutrient required for proper growth and development, the presence of zinc can affect the body's metabolism of other metals.

This study evaluates the potential human health effects associated with the ingestion of fish from the Tri-State Mining Area in Oklahoma. In addition, an evaluation of possible relationships between metals concentrations in fish tissue and metals concentrations in water and sediment was done. Fish tissue concentrations were also compared to values from the National Contaminant Biomonitoring Program conducted by the U.S. Fish and Wildlife Service.

Monitoring Methods

Sample Collection

Fish were collected from 4 ponds and 6 river sites in 2002 (Figure 1, Table1). The river sites were evenly split with 3 sites on Spring River and 3 sites on the Neosho River. Two of the pond sites were millponds at former ore processing locations and 2 pond sites were adjacent to and received runoff from chat piles. The pond sites are located in the Tar Creek Superfund area while the stream sites are outside the Superfund area proper but within the larger Tri-state Mining District.

Table 1. Site Locations

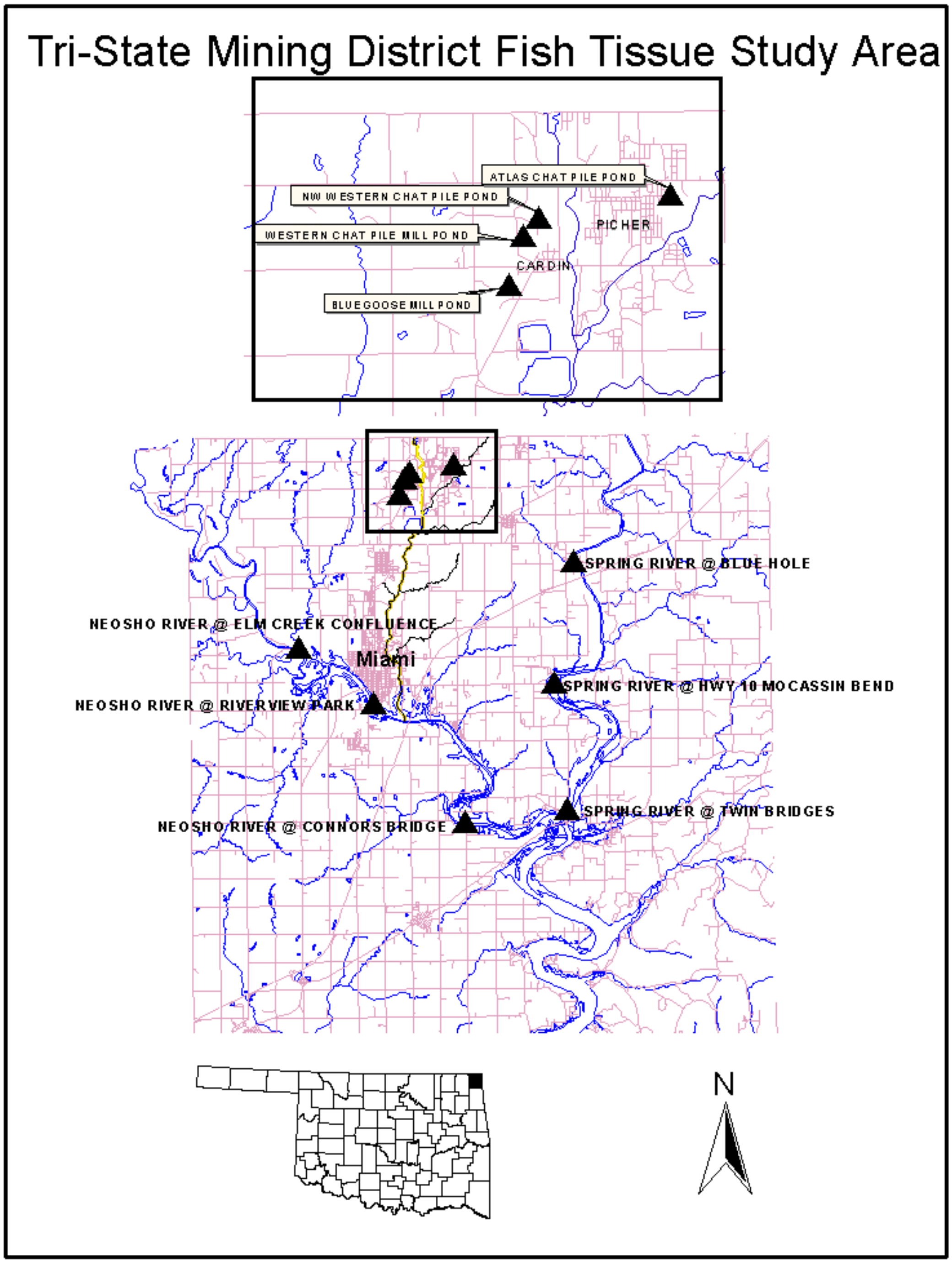
Site ID	Site Name	Latitude	Longitude
TC-MPACP	Atlas Chat Pile Pond	36°58.867’	94°48.332’
TC-MPBG	Blue Goose Mill Pond	36°58.102’	94°51.784’
TC-MPNWWC	Northwest Western Chat Pile Pond	36°59.081’	94°51.349’
TC-MPWCP	Western Chat Pile Mill Pond	36°58.920’	94°51.436’
TC-NRCB	Neosho River at Conners Bridge	36°47.949’	94°49.165’
TC-NRECC	Neosho River at Elm Creek Confluence	36°53.470’	94°55.677’
TC-NRRP	Neosho River at Riverview Park	36°51.944’	94°52.728’
TC-SRBH	Spring River at Blue Hole	36°56.096’	94°44.765’
TC-SRMB	Spring River at Mocassin Bend	36°52.311’	94°45.933’
TC-SRTB	Spring River at Twin Bridges State Park	36°48.174’	94°45.213’

A total of 80 composite fish samples representing 8 species were collected using various combinations of electrofishing, gill nets, and rod and reel. Species targeted for collection and analysis were carp, channel catfish and white crappie. At sites where those species were not available in sufficient numbers, other commonly consumed species were collected. These include white bass, spotted bass, largemouth bass, bluegill sunfish and smallmouth buffalo. Because comparisons were to be made between different preparation methods, an attempt was made to collect consistent size ranges within species at all sites.

Laboratory Analysis

Fish collections were delivered to ODEQ’s State Environmental Laboratory where they were sorted by site, species, and size. Fish were then sorted into composites consisting of 3 to 8 individuals with the smallest fish in the composite at least 75 percent of the length of the largest fish in the composite. Composite samples of similar mean length were assembled for different preparation methods: fillets, whole-uneviscerated fish, and whole-eviscerated fish. Sufficient numbers of fish were available to perform analyses using the 3 preparation methods for carp and channel catfish at the 6 river sites, white crappie at 5 of the river sites, and largemouth bass at the 4 pond sites. In addition, 25 composite samples consisting of other commonly consumed species were assembled.

Figure1. Sampling Locations



A sample preparation technique[1] was developed to prevent cross-contamination between samples as metals are found in both the mucous and scales of fish. Only stainless steel cutting utensils were used and the preparation surfaces were sheeted in polyethylene. All utensils and equipment were thoroughly cleaned and polyethylene sheeting replaced between the preparation of each sample.

Fish were skinned and filleted, simply eviscerated, or kept whole as appropriate. A commercial grade food grinder with stainless steel cutting blades was used to mascerate samples. The ground tissue was then homogeneously mixed before being sent through the food grinder a second time. A subsample of the ground tissue was then collected for analysis.

A microwave digestion technique[2] was developed to prepare the subsamples for analysis. One gram subsamples were digested in 10 milliliters of concentrated nitric acid (HNO_3) brought to 200^{o} C under pressure in a four-step temperature ramping process. Samples were held at 200^{o} C for 10 minutes and then allowed to cool for 15 minutes. All tissue, including bones if present, was at that point dissolved into the HNO_3. Digested sample aliquots were then diluted with ultra-pure water to a volume of 50 mls and allowed to rest.

EPA Method 200.7[3] for the analysis of metals was used to analyze the fish tissue samples. Digested samples were diluted again by 50 percent to create a 10% HNO_3 solution just before analysis on an inter-coupled plasma (ICP) Trace® Analyzer. A 10 mil. aliquot of the digested sample was injected into the ICP and 3 readings of each element were recorded. The mean of the 3 readings as well as the standard deviation was calculated. If the percent of the standard deviation relative to the mean of the 3 readings exceeded 20 percent, the sample results were rejected. The mean of the readings was used to calculate the amount of each element in the 1-gram aliquot of digested fish flesh. This value was then converted to mg/kg units and entered into the AQUARIUS laboratory information system.

Quality Assurance

A total of 4 field replicate samples were submitted for fish. These consisted of duplicate composite samples of the same species, similar in size, collected at the same site. Each of the sample preparation methods was represented by a field replicate. Precision values were all 0 percent for cadmium (all values below the laboratory reporting limit), 7 to 14 percent for zinc, and 0 to 4 percent for lead. All precision values fall within acceptable limits for field replicate samples as outlined the Quality Assurance Project Plan[4] for this study.

A total of 8 laboratory duplicate samples of fish tissue were prepared. These consisted of duplicate subsamples of the ground composited tissue. These were digested and analyzed alongside the rest of the samples. Precision values were all 0 percent for cadmium (all values below the reporting limit), 1 to 25 percent for zinc, and 0 to 18 percent for lead. All precision values fall within acceptable limits for laboratory duplicates as outlined in the Quality Assurance Project Plan for this study.

Results

Results for all analyses are included in Appendix A.

Data Analysis

Determination of Safe Consumption Levels

The determination of safe fish consumption levels for lead, zinc, and cadmium was performed using 2 different methods. Zinc and cadmium levels were determined by using methods described in the U.S. EPA document *Guidance For Assessing Chemical Contaminant Data For Use in Fish Advisories*[5]. This method utilizes Reference Dose values (RfDs) to calculate contaminant exposure levels that would likely not result in an appreciable risk of adverse heath effects over a lifetime. The level for lead was determined using EPA's Integrated Exposure Uptake Biokinetic (IEUBK) Model for Lead[6]. This model considers total environmental lead exposure and predicts the blood lead levels for children up to 84 months of age. A method similar to one utilized by the Washington State Department of Health[7] was used to establish the allowable levels of lead in fish tissue. Since children are more sensitive to the deleterious effects of lead, the consumption recommendations for lead are based on the protection of children. It is assumed that levels that are protective of children are also protective of adults.

To address the issue of elevated consumption rates among tribal members, safe consumption levels were calculated using two different consumption rates: 1 meal per week as the Standard Consumption Rate and 2 meals per week as the Elevated Consumption Rate.

Cadmium and Zinc
For cadmium and zinc safe consumption levels were calculated using the following equations:

$$C_m = (RfD \times BW)/CR_{lim}$$

Where

C_m = measured concentration of chemical contaminant *m* in a given species of fish (mg/kg)
RfD = reference dose (mg/kg-day)
BW = consumer body weight (kg)
CR_{lim} = maximum allowable fish consumption rate (kg/d)

and:

$$CR_{lim} = (CR_{mw} \times MS)/T_{ap}$$

Where

CR_{mw} = maximum allowable fish consumption rate (meals/week)
MS = meal size (kg fish/meal)
T_{ap} = time averaging period (days/week)

Combining equations yields:

$$C_m = (RfD \times BW \times T_{ap})/(CR_{mw} \times MS)$$

Reference dose values were obtained from the EPA Integrated Risk Information System (IRIS) database[8,9]. Default values obtained from EPA's *Guidance For Assessing Chemical Contaminant Data For Use in Fish Advisories*[5] were used for body weight and meal size. Equation inputs are as follows:

Reference Dose	Cadmium = 0.001mg/kg-day
	Zinc = 0.3 mg/kg-day
Body weight	Children = 14.5 kg (32lb)
	Adults = 70 kg (154 lb)
Meal Size	0.227 kg (8 oz)
Consumption Rate	Standard Rate = 1 meal/week
	Elevated Rate = 2 meals/week
Time averaging Period	7 days/week

From this, the following allowable fish contaminant concentrations were calculated:

Standard Rate:

	Children	Adults
Cadmium	0.45 mg/kg	2.2 mg/kg
Zinc	135 mg/kg	650 mg/kg

Elevated Rate:

	Children	Adults
Cadmium	0.22 mg/kg	1.1 mg/kg
Zinc	67 mg/kg	325 mg/kg

The State Environmental Laboratory's reporting limit for cadmium (0.30 mg/kg) is above the safe concentration calculated using the elevated consumption rate for children. Because of this, either the meal size or the consumption rate could be adjusted to determine safe levels of consumption of fish based on results at the reporting limit. Calculations of safe consumption levels based on a fish concentration of 0.30 mg/kg are as follows:

For a meal size of 0.227 kg (8 oz):

$$CR_{mw} = (RfD \times BW \times T_{ap})/(C_m \times MS)$$

$$= (0.001 \times 14.5 \times 7)/(0.30 \times 0.227)$$

$$= 1.5 \text{ meals/week}$$

For a consumption rate of 2 meals per week:

$$MS = (RfD \times BW \times T_{ap})/(C_m \times CR_{mw})$$

$$= (0.001 \times 14.5 \times 7)/(0.30 \times 2)$$

$$= 0.169 \text{ kg (6 oz) fish meal}$$

Lead

Safe fish concentration levels for lead were calculated using the IEUBK model which predicts the distribution of blood lead levels for children age 84 months and younger. The model generates a protective level at which no more than 5 percent of modeled blood lead levels exceed the EPA Intervention Level[10] of 10 ug/dl (micrograms/deciliter). Blood lead concentrations above the Intervention Level indicate action should be taken to determine the cause of the elevated concentration. This risk assessment methodology is more conservative than that used for cadmium and zinc in that total lead exposure is accounted for through estimates of exposure through soil, house dust, air, water, and diet. EPA default values were used for all inputs into the IEUBK except for soil and house dust lead concentrations, and factors related to fish consumption and concentration.

Soil lead concentrations were determined by computing the 95% upper confidence level(UCL) of the mean of yard soil concentrations[11]and high access area concentrations[12]. Residential yards and high access areas(HAAs) such as parks, schools and playgrounds have been sampled for lead concentration as part of the cleanup activities in the Tar Creek area. If yard or HAA soil concentrations were found to have soil lead levels greater than 500 mg/kg, the soil was removed and replaced with low lead concentration borrow fill soil from outside the area. Yard and HAA replacement activities are nearing completion at the time this report is being written.

Yard lead data indicate that 3257 of 7977 samples (41%) exceed 500 mg/kg. These areas were replaced with borrow fill having a mean lead concentration of 18.1 mg/kg[13]. The mean value of the yards after remediation was calculated after replacing those values greater than 500 mg/kg in the dataset with values of 18.1 mg/kg. The resulting mean of the post-remediation yards is 140.9 mg/kg. The 95% UCL for the mean is 144.2 mg/kg.

A total of 28 high access areas were sampled in the towns of Picher, Cardin, Quapaw, Commerce, and North Miami. Ten of the 28 eight sites (36%) averaged greater than 500 mg/kg soil lead level. The soil at these sites was removed and replaced with borrow fill having a mean lead value of 18.1 mg/kg. The mean value of the HAAs after remediation was calculated after replacing the values of sites that were greater than 500 mg/kg with 18.1 mg/kg. The resulting mean of the post-remediated HAAs was 134.7 mg/kg. The 95% UCL for the mean was 163.8 mg/kg

Based on this information it was decided to use a soil concentration input of 165 mg/kg. The IEUBK default for soil concentration to house dust concentration is 0.7. Using this, the house dust concentration was calculated to be 115 mg/kg. Inputs into the IEUBK model are given in Table 2.

Table 2. IEUBK Inputs

Input	Value
Drinking Water	4.00 ug/L (EPA default value)
Soil	165 mg/kg (based on the 95% UCL of the mean of yard soil levels and high access area soil levels)
House Dust	115 ug/g (based on soil level)
Paint	0 per day (EPA default)
Maternal Blood Contribution	2.5 ug/dl (default in the infant model)
Outdoor Air Concentration	0.100 ug/m^3 (EPA default)
Indoor Air	30% of outdoor air concentration (EPA default)
Time Outdoors	1 to 4 hours per day (EPA defaults based on age)
Ventilation Rates	2 to 7 m^3/day (EPA defaults based on age range)
Lung Absorption	32 percent (EPA default)
Diet Uptake	50% (EPA default varies slightly with age)
Water Uptake	0.36 to 1.13 ug/day (EPA default, varies with age)
Soil and Dust Uptake	5.1 to 5.67 ug/day (EPA default varies with age)
Percentage of Meat Intake Consisting of Locally Caught Fish	Standard Consumption Rate: 32 percent Elevated Consumption Rate: 64 percent (based on one or two 8-ounce meals per week as a percentage of median EPA default daily meat consumption of 101.57 g/day based on age)

The allowable lead concentration in fish was determined by setting the model inputs to those described in Table 2 and manipulating the *Lead in Fish* concentration to a level that results in just less than 5 percent of the target population with a blood lead level of 10 ug/dl.

For example, in the case of the Standard Consumption Rate of one 8-ounce meal per week, the model was initially run with the *Percentage of Meat Intake Consisting of Locally Caught Fish* input at 32 percent and the *Lead in Fish* concentration set to 0 mg/kg resulting in 0.44 percent of the target population with a blood lead level greater than 10 ug/dl. The *Lead in Fish* concentration was incrementally increased until just below 5 percent of the target population had a blood lead level of more than 10 mg/dl. That final *Lead in Fish* concentration was 0.36 mg/kg.

This process was repeated for an Elevated Consumption Rate of two 8-ounce meals per week of locally caught fish. The resulting allowable lead level was 0.18 mg/kg.

Allowable fish contaminant concentrations based on either one or two 8-ounce meals per week are as follows:

Contaminant	Children Standard Consumption Rate	Children Elevated Consumption Rate	Adults Standard Consumption Rate	Adults Elevated Consumption Rate
Lead	0.36 mg/kg	0.18 mg/kg	0.36 mg/kg	0.18 mg/kg
Cadmium	0.45 mg/kg	0.22 mg/kg	2.2 mg/kg	1.1 mg/kg
Zinc	135 mg/kg	67 mg/kg	650 mg/kg	325 mg/kg

As in the case of cadmium, the allowable lead in fish concentration at the Elevated Consumption Rate of two 8-ounce meals per week was less than the State Environmental Laboratory's reporting limit of 0.25 mg/kg. To determine a safe consumption level based on the SEL's reporting limit, the *Lead in Fish* concentration was set to 0.25 mg/kg and the *Percentage of Meat Intake Consisting of Locally Caught Fish* input was initially set at 64 percent (two 8-ounce meals per week.) This resulted in 7.8 percent of the target population with a blood level exceeding 10 ug/dl. The *Percentage of Meat Intake Consisting of Locally Caught Fish* input was then incrementally reduced until just under 5 percent of the target population had an acceptable blood lead level. That final level was 47%.

Allowable fish consumption based on the SEL's reporting limit of 0.25 mg/kg was calculated as follows:

CR_{Lim} = (M_{DI} X P_F X T_{AP} X 0.0353 ounces/gram)/8 ounces/meal where

CR_{Lim} = Consumption rate in meals/month
M_{DI} = median daily consumption of meat by children younger than 8
P_F = Proportion of meat intake consisting of locally caught fish

CR_{Lim} = (101.57 g/day X 0.51 X 7 days/week X 0.0353 oz/g)/8 oz/meal
= 1.5 meals/week

or for a consumption rate of 2 meals per week:

MS = (CR_{LIM} X P_F X T_{AP} X 0.0353 oz/g)/2 meals/week
= (101.57g/day X 0.51 X 7 days/week X 0.0353 oz/g) / 2 meals/week
= 5.9 oz. fish meal

Comparison of Collected Fish Concentrations to Allowable Levels

Fish were collected at 3 sites on Spring River, 3 sites on the Neosho River, 2 ponds near chat piles and 2 millponds at former ore processing sites. Sample analysis was performed on whole-uneviscerated fish, whole-eviscerated fish and fillets of carp and channel catfish at the 6 river sites, white crappie at 5 of the river sites, and largemouth bass at the 4 pond sites. In addition, 25 samples of various other commonly consumed species were performed using the various preparation methods.

Table 3 lists the percentage of samples (by preparation method and species) exceeding the allowable fish contaminant concentrations at the Standard Consumption Rate. Table 4 lists the percentage of samples exceeding the allowable fish contaminant concentrations at the Elevated Consumption Rates.

Table 3. Percentage of Samples Exceeding Allowable Contaminant Concentration Levels at Standard Consumption Rates (1 meal per week).

Preparation	Number of Samples	Cadmium Children (percent exceeding 0.45 mg/kg)	Cadmium Adults (percent exceeding 2.2 mg/kg)	Lead Children and Adults (percent exceeding 0.36 mg/kg)	Zinc Children (percent exceeding 135 mg/kg)	Zinc Adults (percent exceeding 650 mg/kg)
All Species						
All	80	3	0	27	0	0
FL	25	0	0	0	0	0
WE	25	0	0	24	0	0
WU	30	7	0	50	0	0
Smallmouth Buffalo						
All	4	0	0	100	0	0
FL	0	0	0	0	0	0
WE	0	0	0	0	0	0
WU	4	0	0	100	0	0

Preparation	Number of Samples	Cadmium Children (percent exceeding 0.45 mg/kg)	Cadmium Adults (percent exceeding 2.2 mg/kg)	Lead Children and Adults (percent exceeding 0.36 mg/kg)	Zinc Children (percent exceeding 135 mg/kg)	Zinc Adults (percent exceeding 650 mg/kg)
Carp						
All	18	11	0	56	0	0
FL	6	0	0	0	0	0
WE	6	0	0	67	0	0
WU	6	33	0	100	0	0
Channel Catfish						
All	18	0	0	17	0	0
FL	6	0	0	0	0	0
WE	6	0	0	0	0	0
WU	6	0	0	33	0	0
Bluegill Sunfish						
All	5	0	0	40	0	0
FL	1	0	0	0	0	0
WE	1	0	0	0	0	0
WU	3	0	0	66	0	0
Largemouth Bass						
All	13	0	0	15	0	0
FL	4	0	0	0	0	0
WE	4	0	0	25	0	0
WU	5	0	0	20	0	0
Spotted Bass						
All	3	0	0	0	0	0
FL	1	0	0	0	0	0
WE	1	0	0	0	0	0
WU	1	0	0	0	0	0
White Bass						
All	2	0	0	0	0	0
FL	0	0	0	0	0	0
WE	0	0	0	0	0	0
WU	2	0	0	0	0	0
White Crappie						
All	15	0	0	0	0	0
FL	5	0	0	0	0	0
WE	5	0	0	0	0	0
WU	5	0	0	0	0	0

Preparation Codes:

ALL – All Sample Preparations
FL – Fillet
WE – Whole-eviscerated
WU – Whole-uneviscerated

Table 4. Percentage of Samples Exceeding Allowable Contaminant Concentration Levels at Elevated Consumption Rates (2 meal per week).

Preparation	Number of Samples	Cadmium Children (percent exceeding 0.22 mg/kg)	Cadmium Adults (percent exceeding 1.1 mg/kg)	Lead Children and Adults (percent exceeding 0.18 mg/kg)	Zinc Children (percent exceeding 67 mg/kg)	Zinc Adults (percent exceeding 325 mg/kg)
All Species						
All	80	6	0	36	1	0
FL	25	0	0	4	0	0
WE	25	0	0	36	0	0
WU	30	20	0	60	3	0
Smallmouth Buffalo						
All	4	0	0	100	0	0
FL	0	0	0	0	0	0
WE	0	0	0	0	0	0
WU	4	0	0	100	0	0
Carp						
All	18	28	0	66	6	0
FL	6	0	0	17	0	0
WE	6	0	0	83	0	0
WU	6	83	0	100	17	0
Bluegill Sunfish						
All	5	0	0	40	0	0
FL	1	0	0	0	0	0
WE	1	0	0	0	0	0
WU	3	0	0	66	0	0
Channel Catfish						
All	18	0	0	28	0	0
FL	6	0	0	0	0	0
WE	6	0	0	33	0	0
WU	6	0	0	50	0	0
Largemouth Bass						
All	13	0	0	23	0	0
FL	4	0	0	0	0	0
WE	4	0	0	50	0	0
WU	5	0	0	20	0	0
Spotted Bass						
All	3	0	0	0	0	0
FL	1	0	0	0	0	0
WE	1	0	0	0	0	0
WU	1	0	0	0	0	0
White Bass						
All	2	0	0	0	0	0
FL	0	0	0	0	0	0
WE	0	0	0	0	0	0
WU	2	0	0	0	0	0

Preparation	Number of Samples	Cadmium Children (percent exceeding 0.22 mg/kg)	Cadmium Adults (percent exceeding 1.1 mg/kg)	Lead Children and Adults (percent exceeding 0.18 mg/kg)	Zinc Children (percent exceeding 67 mg/kg)	Zinc Adults (percent exceeding 325 mg/kg)
White Crappie						
All	15	0	0	13	0	0
FL	5	0	0	0	0	0
WE	5	0	0	0	0	0
WU	5	0	0	40	0	0

Preparation Codes:

ALL – All Sample Preparations
FL – Fillet
WE – Whole-eviscerated
WU – Whole-uneviscerated

From the two tables the following can be discerned:

- A single fillet sample of carp exceeded allowable levels for lead and the Elevated Consumption Rate. No other fillet portions of any fish exceeded laboratory reporting limits. No fillet portions exceed allowable levels for any metal tested at the Standard Consumption Rate.

- Allowable levels for cadmium at the Elevated Consumption Rate for children were exceeded only in samples of whole-uneviscerated carp.

- The allowable level for Zinc at the Elevated Consumption Rate for Children was exceeded by a single whole fish sample.

- Allowable levels for lead at the elevated consumption rate were exceeded in 36 percent of all whole-eviscerated samples and 60 percent of all whole fish samples.

- Allowable levels of lead at the Standard Consumption Rate of 1 meal per week were exceeded in 5 species:
  - 33 percent of whole-uneviscerated channel catfish
  - 17 percent of whole-eviscerated channel catfish
  - 100 percent of whole-uneviscerated smallmouth buffalo
  - 100 percent of whole-uneviscerated carp
  - 67 percent of whole-eviscerated carp.
  - 66 percent of whole-uneviscerated bluegill
  - 20 percent of whole-uneviscerated largemouth bass
  - 25 percent of whole-eviscerated largemouth bass

- Allowable levels of lead at the Elevated Consumption Rate of 2 meals per week were exceeded in 5 species:
  - 50 percent of whole-uneviscerated channel catfish
  - 33 percent of whole-eviscerated channel catfish

- 20 percent of whole-uneviscerated largemouth bass
- 50 percent of whole-eviscerated largemouth bass
- 66 percent of whole-uneviscerated bluegill sunfish
- 40 percent of whole-eviscerated white crappie
- 17 percent of carp fillets
- 83 percent of whole-eviscerated carp
- 100 percent of whole-uneviscerated carp
- 100 percent of whole-uneviscerated smallmouth buffalo

Based on this information ODEQ recommends children living in the Tar Creek area consume no more than six 8-ounce fillet meals per month of fish caught in ponds within the Tar Creek Superfund Site and the Spring and Neosho Rivers above Grand Lake. All adults and children should avoid eating all species of whole-eviscerated or whole-uneviscerated fish caught in these waters.

Comparison of Preparation Methods

Fish samples were analyzed using 3 different preparation methods: fillets, whole-eviscerated, and whole-uneviscerated. There are 23 instances in the data set where analyses were performed using the three preparation methods on the same species from the same site. These data were pooled and statistical tools were applied to determine if significant differences exist between the preparation methods in relation to tissue metals concentration. Figures 3-5 illustrate boxplots of results from the 3 preparation methods vs. metals concentration. Figure 2 is a legend defining boxplot construction as used in this report.

Figure 2. Boxplot construction legend.

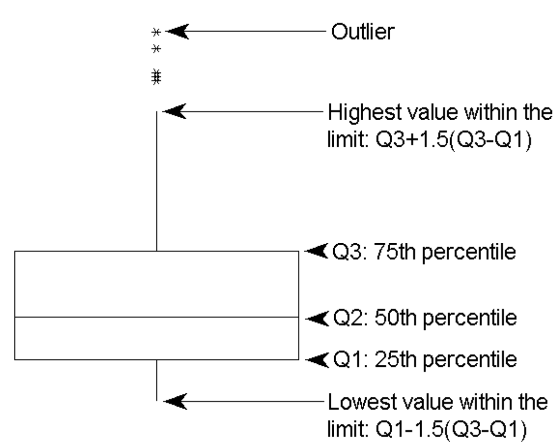


Figure 3. Boxplots of cadmium concentration by sample preparation (all species pooled.)

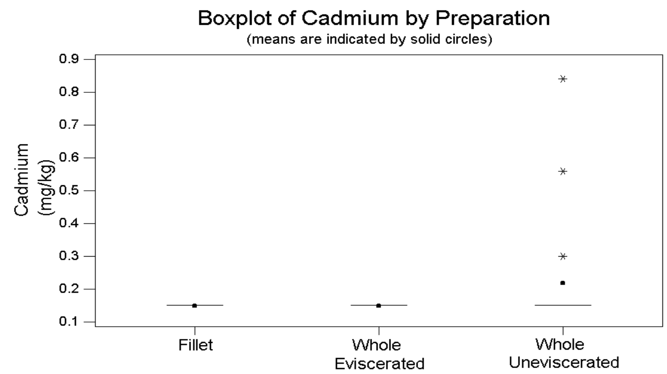


Figure 4. Boxplots of lead concentration by sample preparation (all species pooled.)

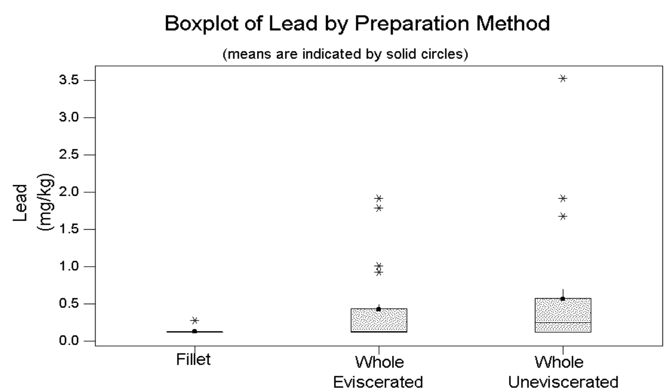
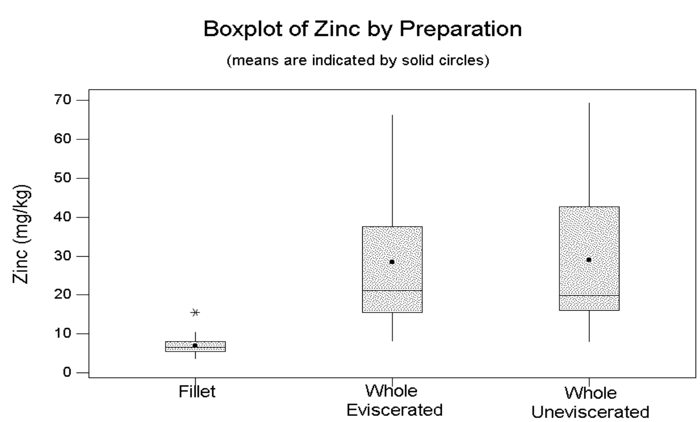


Figure 5. Boxplots of zinc concentration by sample preparation (all species pooled.)



These plots indicate some differences between the whole-eviscerated and the whole-uneviscerated preparations while illustrating generally lower concentrations in fillet samples. To confirm these observations, a Kruskal-Wallis test[14] was applied to the data. The Kruskal-Wallis test uses median values and average ranks to determine if the observed differences in 2 or more populations are statistically significant, that is, of a greater magnitude than would be expected to occur by chance. The Kruskal-Wallis test is an extension of the Wilcoxon Rank Sum test and does not require the distribution of the data to be normal or symmetric. For this test all values below the laboratory reporting limit were set to one-half the reporting limit. The results are as follows:

H_0: The medians of the preparation methods are all equal.
H_A: At least one of the medians is larger or smaller than at least one of the other medians.
$\alpha = 0.05$

For Cadmium:

Preparation	Number of Samples	Median	Average Rank	*Z* Statistic
Fillet	23	0.15	32.5	-0.73
Whole Eviscerated	23	0.15	32.5	-0.73
Whole Uneviscerated	23	0.15	40.0	1.46
Overall	69		35.0	

H Statistic = 10.61 Degrees of Freedom = 2 p = 0.005 (adjusted for ties)

For Lead:

Preparation	Number of Samples	Median	Average Rank	*Z* Statistic
Fillet	21	0.125	22.6	-2.87
Whole Eviscerated	21	0.125	35.0	0.93
Whole Uneviscerated	21	0.250	38.6	1.93
Overall	63		32.0	

H Statistic = 12.14 Degrees of Freedom = 2 p = 0.002 (adjusted for ties)

For Zinc:

Preparation	Number of Samples	Median	Average Rank	*Z* Statistic
Fillet	23	6.54	13.0	-6.45
Whole-Eviscerated	23	21.2	45.9	3.18
Whole-Uneviscerated	23	19.9	46.5	3.27
Overall	69		35.0	

H Statistic = 41.65 Degrees of Freedom = 2 p = < 0.001

These results indicate that in each case the null hypothesis is rejected in favor of the alternative hypothesis: at least one of the preparation methods differs from at least one of the other preparation methods. The Z statistic indicates how the mean rank for the group differs from the mean rank for all the observations.

From this information and the boxplots one can conclude that in the case of cadmium, the whole-uneviscerated portion is significantly higher than both fillets and whole-eviscerated preparations. For lead, fillet concentrations are significantly less than concentrations in whole-uneviscerated and whole-eviscerated portions. For zinc, fillet concentrations are also significantly lower than both whole-eviscerated and whole-uneviscerated portions.

Relationship of Tissue Concentrations to Sediment and Water Concentrations.

The relationship of tissue metals concentrations to water and sediment levels was explored through linear regression analysis. To be consistent and to provide the most unbiased data, metals concentrations from whole-uneviscerated carp samples (the response variable) were plotted versus water and sediment concentrations (predictor variables). The regression equation was computed along with values for R^2 and *S*. R^2 is the percentage of variation in the response variable due to the predictor variable and *S* is an estimator of the standard deviation around the regression line.

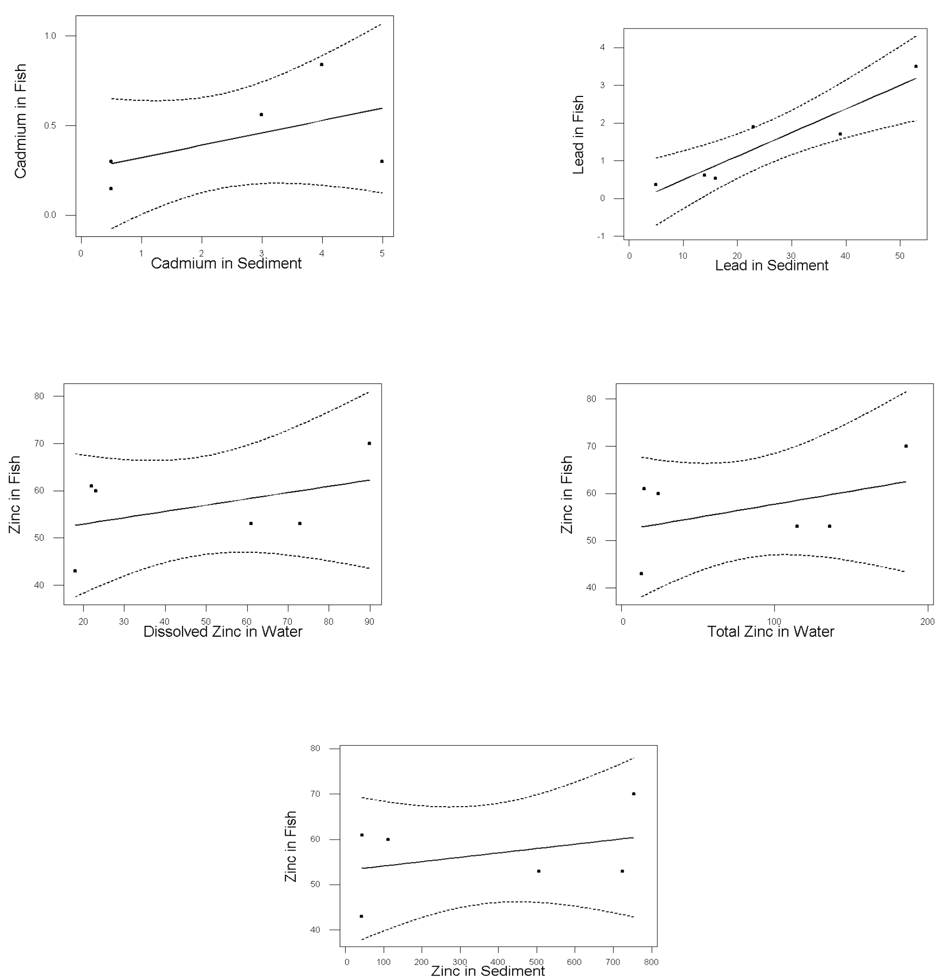
Regression analysis was not run for total and dissolved fractions of lead and cadmium in water because all results were less than the reporting limit. For all other fractions, values less than the reporting limit were set to one-half of the reporting limit.

Of the various combinations of tissue concentration vs. media concentration, only lead in fish vs. lead in sediment yielded a result indicating a solid relationship between the two. The results are given in Table 3 and shown in Figure 5.

Table 5. Regression Results

Test	Regression Equation	S	R^2
Cadmium in Fish vs. Cadmium in Sediment	$Cd_{(fish)} = 0.253 + 0.069\ Cd_{(Sed)}$	0.231	31.0 %
Lead in Fish vs. Lead in Sediment	$Pb_{(fish)} = 0.132 + 0.063\ Pb_{(Sed)}$	0.497	86.3 %
Zinc in Fish vs. Dissolved Zinc in Water	$Zn_{(fish)} = 50.3 + 0.133\ Zn_{(Diss)}$	9.175	20.1 %
Zinc in Fish vs. Total Zinc in Water	$Zn_{(fish)} = 52.1 + 0.056\ Zn_{(Tot)}$	9.170	20.2 %
Zinc in Fish vs. Zinc in Sediment	$Zn_{(fish)} = 53.2 + 0.010\ Zn_{(Sed)}$	9.594	12.6 %

Figure 6. Regression Plots



Comparison to Historic Data

ODEQ intended to compare data collected for this study to data collected from the region in 1982 by the Oklahoma State Department of Health[15] to determine if tissue values were changing over time. However, an examination of the 1982 data revealed that all samples were fillets analyzed only for lead and all results were below the reporting limit at the time of 1.0 mg/kg compared to a reporting limit of 0.25 mg/kg for this study. This makes a comparison of the 2 time periods unsuitable due to the differing reporting limits and the censoring of all 1982 data.

Comparison to National Data

Whole-uneviscerated fish data from this study was compared to data collected for the U.S. Fish and Wildlife Service National Contaminant Biomonitoring Program[16] (NCBP) to determine if tissue metals concentrations in fish collected from the Tri-State Mining District differed from values of fish collected nationwide. The NCBP data was queried to select concentration values representing the same species and size ranges within those species as was collected for the Tri-State Mining District study. Data were labeled as to study and were pooled into a single database.

One of the difficulties in comparing the 2 data groups was the difference in reporting limits for lead and cadmium. The NCBP study used varying reporting limits of 0.001 to 0.05 mg/kg for cadmium and 0.008 to 0.1 mg/kg for lead. The Tri-State Mining District study used reporting limits of 0.3 mg/kg for cadmium and 0.25 mg/kg for lead. For this comparison, all cadmium values below 0.3 mg/kg were set to 0.29 mg/kg and all lead values below 0.25 mg/kg were set to 0.24 mg/kg. The Kruskal-Wallis test was run on the pooled data to determine if there were statistical differences between the 2 study populations.

The results are as follows and boxplots illustrating the data are as follows:

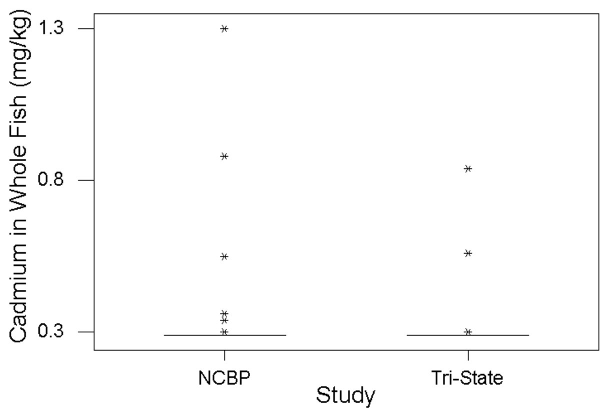
H_0: The medians of the 2 study populations are equal.
H_A: One of the medians is larger or smaller than the other median.
$\alpha = 0.05$

For Cadmium:

Preparation	Number of Samples	Median	Average Rank	*Z* Statistic
NCBP	409	<0.30	217.2	-1.41
Tri-State	29	<0.30	251.6	
Overall	438		219.5	

H Statistic = 1.99	Degrees of Freedom = 1	p = 0.158
H Statistic(adjusted for ties) = 27.13	Degrees of Freedom = 1	p = <0.001

Figure 7. Boxplot comparing cadmium results for NCBP and Tri-State studies.

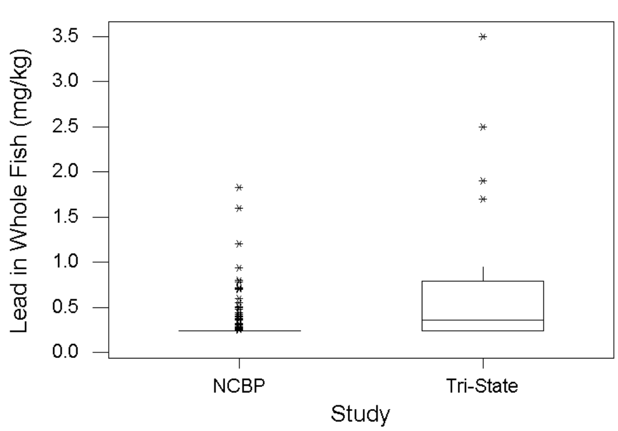


For Lead:

Preparation	Number of Samples	Median	Average Rank	*Z* Statistic
NCBP	409	<0.25	211.2	-5.17
Tri-State	29	0.36	336.9	
Overall	438		219.5	

H Statistic = 26.73	Degrees of Freedom = 1	p = <0.001
H Statistic(adjusted for ties) = 72.75	Degrees of Freedom = 1	p = <0.001

Figure 8. Boxplot comparing lead results for NCBP and Tri-State studies.

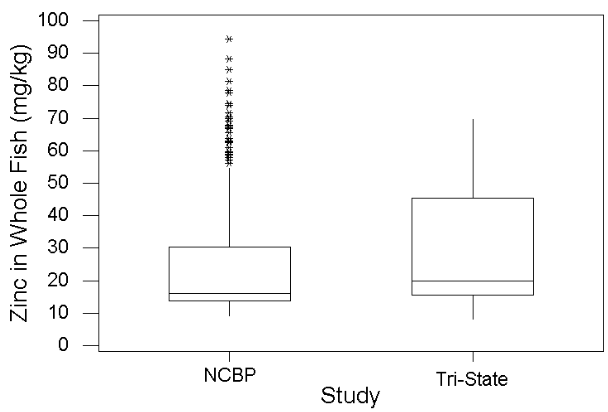


For Zinc:

Preparation	Number of Samples	Median	Average Rank	*Z* Statistic
NCBP	148	15.96	86.4	-1.52
Tri-State	29	20.00	102.2	
Overall	177		219.5	

H Statistic = 2.30 Degrees of Freedom = 1 p = 0.129

Figure 9. Boxplot comparing Zinc results for NCBP and Tri-State studies.



These results indicate the median level for lead in fish tissue collected from waters in the Tri-State Mining District is significantly higher than what would one would expect to find in fish from other waters. The results for cadmium are inconclusive due to the high proportion of censored data. While the calculated median value for zinc is higher in the Tri-State Study, it is not statistically significant at the 95% confidence level.

Conclusions and Recommendations

In comparison to fish collected in the National Contaminant Biomonitoring Program, the fish from Oklahoma waters in the Tri-State Mining Area have lead concentrations higher than one would expect to find in fish from waters elsewhere in the United States. The elevated levels of lead in the fish positively correlate to the concentration of lead in the sediments of these waters. The consumption of whole-eviscerated or whole-uneviscerated fish from these waters is discouraged. However, the consumption of fillets from fish in this area is safe at rates at least as high as six 8-ounce meals per month based on the laboratory reporting limit.

Further study is needed to validate these findings and to determine the downstream extent of the metals uptake in fish species. Specifically, fish from Grand Lake need to be tested for tissue lead concentrations. Additionally, due to local fish harvesting practices, other bottom dwelling fish such as various species of suckers should be included in a follow-up study. Laboratory analytical techniques should be modified to lower reporting limits to levels in the 0.15 mg/kg range for lead and cadmium.

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Appendix A: Data Tables

Site: TC-MPACP Atlas Chat Pile Pond

Dissolved Oxygen (mg/l)	pH	Specific Conductance (umhos/cm)	Water Temperature (deg C)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Solids, Suspended (mgl/l)	Dissolved Cadmium (ug/l)	Total Cadmium (ug/l)	Dissolved Lead (ug/l)	Total Lead (ug/l)	Dissolved Zinc (ug/l)	Total Zinc (ug/l)	Cadmium, Sediment (mg/kg)	Lead, Sediment (mg/kg)	Zinc, Sediment (mg/kg)
6.48	7.57	2639	20.6												

Species	Mean Length (inches)	Mean Weight (grams)	Sample Preparation	QA Category	Cadmium in Fish (mg/kg)	Lead in Fish (mg/kg)	Zinc in Fish (mg/kg)
Bass. large mouth	10.25	194	Fillet	Sample	< 0.30	< 0.25	11
Bass. large mouth	10.94	269	Whole Eviscerated	Sample	< 0.30	0.28	30
Bass. large mouth	11.63	300	Whole Uneviscerated	Sample	< 0.30	0.70	32

Site: TC-MPBG Blue Goose Mill Pond

Dissolved Oxygen (mg/l)	pH	Specific Conductance (umhos/cm)	Water Temperature (deg C)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Solids, Suspended (mgl/l)	Dissolved Cadmium (ug/l)	Total Cadmium (ug/l)	Dissolved Lead (ug/l)	Total Lead (ug/l)	Dissolved Zinc (ug/l)	Total Zinc (ug/l)	Cadmium, Sediment (mg/kg)	Lead, Sediment (mg/kg)	Zinc, Sediment (mg/kg)
7.54	7.74	1409	23.6												

Species	Mean Length (inches)	Mean Weight (grams)	Sample Preparation	QA Category	Cadmium in Fish (mg/kg)	Lead in Fish (mg/kg)	Zinc in Fish (mg/kg)
Bass. large mouth	11.56	329	Fillet	Sample	< 0.30	< 0.25	4.3
Bass. large mouth	13.19	482	Whole Eviscerated	Sample	< 0.30	< 0.25	17
Bass. large mouth	13.56	541	Whole Uneviscerated	Sample	< 0.30	< 0.25	17

Site: TC-MPNWWC   Northwest Western Chat Pile Pond

Dissolved Oxygen (mg/l)	pH	Specific Conductance (umhos/cm)	Water Temperature (deg C)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Solids, Suspended (mgl/l)	Dissolved Cadmium (ug/l)	Total Cadmium (ug/l)	Dissolved Lead (ug/l)	Total Lead (ug/l)	Dissolved Zinc (ug/l)	Total Zinc (ug/l)	Cadmium, Sediment (mg/kg)	Lead, Sediment (mg/kg)	Zinc, Sediment (mg/kg)
11.3	8.48	521	24.2												

Species	Mean Length (inches)	Mean Weight (grams)	Sample Preparation	QA Category	Cadmium in Fish (mg/kg)	Lead in Fish (mg/kg)	Zinc in Fish (mg/kg)
Bass. large mouth	12.58	450	Fillet	Sample	< 0.30	< 0.25	5.5
Bass. large mouth	13.83	614	Whole Eviscerated	Sample	< 0.30	0.38	15
Bass. large mouth	15.33	889	Whole Uneviscerated	Sample	< 0.30	< 0.25	7.9
Bass. large mouth	15.33	889	Whole Uneviscerated	Lab Duplicate	< 0.30	< 0.25	10

Site: TC-MPWCP   Western Chat Pile Mill Pond

Dissolved Oxygen (mg/l)	pH	Specific Conductance (umhos/cm)	Water Temperature (deg C)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Solids, Suspended (mgl/l)	Dissolved Cadmium (ug/l)	Total Cadmium (ug/l)	Dissolved Lead (ug/l)	Total Lead (ug/l)	Dissolved Zinc (ug/l)	Total Zinc (ug/l)	Cadmium, Sediment (mg/kg)	Lead, Sediment (mg/kg)	Zinc, Sediment (mg/kg)
7.58	7.70	1739	23.4												

Species	Mean Length (inches)	Mean Weight (grams)	Sample Preparation	QA Category	Cadmium in Fish (mg/kg)	Lead in Fish (mg/kg)	Zinc in Fish (mg/kg)
Bass. large mouth	8.67	140	Fillet	Sample	< 0.30	< 0.25	5.0
Bass. large mouth	9.50	176	Whole Eviscerated	Sample	< 0.30	< 0.25	16
Bass. large mouth	9.58	190	Whole Uneviscerated	Sample	< 0.30	< 0.25	15
Sunfish, Bluegill	7.80	138	Whole Uneviscerated	Sample	< 0.30	0.37	49

Site: TC-NRCB Neosho River @ Conners Bridge

Dissolved Oxygen (mg/l)	pH	Specific Conductance (umhos/cm)	Water Temperature (deg C)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Solids, Suspended (mgl/l)	Dissolved Cadmium (ug/l)	Total Cadmium (ug/l)	Dissolved Lead (ug/l)	Total Lead (ug/l)	Dissolved Zinc (ug/l)	Total Zinc (ug/l)	Cadmium, Sediment (mg/kg)	Lead, Sediment (mg/kg)	Zinc, Sediment (mg/kg)
10.1	7.48	170.6	16.9	33.2	88.2	52	< 5.0	< 5.0	< 10	< 10	23	24	< 1	16	112

Species	Mean Length (inches)	Mean Weight (grams)	Sample Preparation	QA Category	Cadmium in Fish (mg/kg)	Lead in Fish (mg/kg)	Zinc in Fish (mg/kg)
Carp	19.00	1305	Fillet	Sample	< 0.30	< 0.25	7.8
Carp	20.33	1922	Whole Eviscerated	Sample	< 0.30	0.35	66
Carp	21.25	2016	Whole Uneviscerated	Sample	< 0.30	0.53	60
Catfish, Channel	16.17	550	Fillet	Sample	< 0.30	< 0.25	6.4
Catfish, Channel	16.17	550	Fillet	Lab Duplicate	< 0.30	< 0.25	6.5
Catfish, Channel	16.75	673	Whole Eviscerated	Sample	< 0.30	< 0.25	21
Catfish, Channel	17.25	767	Whole Uneviscerated	Sample	< 0.30	< 0.25	20
Crappie, White	7.75	94	Fillet	Sample	< 0.30	< 0.25	6.2
Crappie, White	8.83	145	Whole Eviscerated	Sample	< 0.30	< 0.25	13
Crappie, White	9.58	215	Whole Uneviscerated	Sample	< 0.30	< 0.25	12

Site: TC-NRECC Neosho River @ Elm Creek Confluence

Dissolved Oxygen (mg/l)	pH	Specific Conductance (umhos/cm)	Water Temperature (deg C)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Solids, Suspended (mgl/l)	Dissolved Cadmium (ug/l)	Total Cadmium (ug/l)	Dissolved Lead (ug/l)	Total Lead (ug/l)	Dissolved Zinc (ug/l)	Total Zinc (ug/l)	Cadmium, Sediment (mg/kg)	Lead, Sediment (mg/kg)	Zinc, Sediment (mg/kg)
9.18	8.10	263.4	13.5	79.0	138	52	< 5.0	< 5.0	< 10	< 10	18	13	< 1	14	43

Species	Mean Length (inches)	Mean Weight (grams)	Sample Preparation	QA Category	Cadmium in Fish (mg/kg)	Lead in Fish (mg/kg)	Zinc in Fish (mg/kg)
Buffalo, Smallmouth	18.30	1524	Whole Uneviscerated	Sample	< 0.30	0.51	15
Carp	17.33	1146	FL	Sample	< 0.30	0.28	8.7
Carp	19.08	1297	Whole Eviscerated	Sample	< 0.30	0.93	54
Carp	19.76	1484	Whole Uneviscerated	Sample	0.30	0.61	43
Catfish, Channel	15.75	442	Fillet	Sample	< 0.30	< 0.25	7.5
Catfish, Channel	15.75	442	Fillet	Lab Duplicate	< 0.30	< 0.25	6.7
Catfish, Channel	17.17	616	Whole Eviscerated	Sample	< 0.30	< 0.25	16
Catfish, Channel	18.17	802	Whole Uneviscerated	Sample	< 0.30	0.35	19
Crappie, White	10.17	236	Fillet	Sample	< 0.30	R	6.5
Crappie, White	10.58	259	Whole Eviscerated	Sample	< 0.30	< 0.25	19
Crappie, White	11.08	317	Whole Uneviscerated	Sample	< 0.30	0.27	16

Site: TC-NRRP Neosho River @ Riverview Park

Dissolved Oxygen (mg/l)	pH	Specific Conductance (umhos/cm)	Water Temperature (deg C)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Solids, Suspended (mgl/l)	Dissolved Cadmium (ug/l)	Total Cadmium (ug/l)	Dissolved Lead (ug/l)	Total Lead (ug/l)	Dissolved Zinc (ug/l)	Total Zinc (ug/l)	Cadmium, Sediment (mg/kg)	Lead, Sediment (mg/kg)	Zinc, Sediment (mg/kg)
4.88	7.22	198.8	17.9	30.7	98.9	72	< 5.0	< 5.0	< 10	< 10	22	15	< 1	< 10	44

Species	Mean Length (inches)	Mean Weight (grams)	Sample Preparation	QA Category	Cadmium in Fish (mg/kg)	Lead in Fish (mg/kg)	Zinc in Fish (mg/kg)
Carp	17.81	1254	Fillet	Sample	< 0.30	< 0.25	6.9
Carp	19.56	1470	Whole Eviscerated	Sample	< 0.30	< 0.25	38
Carp	20.88	1867	Whole Uneviscerated	Sample	0.30	0.36	61
Catfish, Channel	14.08	338	Fillet	Sample	< 0.30	< 0.25	6.1
Catfish, Channel	14.08	338	Fillet	Lab Duplicate	< 0.30	< 0.25	6.2
Catfish, Channel	15.17	394	Whole Eviscerated	Sample	< 0.30	0.28	23
Catfish, Channel	15.83	475	Whole Uneviscerated	Sample	< 0.30	< 0.25	18
Crappie, White	9.92	207	Fillet	Sample	< 0.30	< 0.25	4.7
Crappie, White	10.08	248	Whole Eviscerated	Sample	< 0.30	< 0.25	11
Crappie, White	10.92	299	Whole Uneviscerated	Sample	< 0.30	< 0.25	13
Crappie, White	10.92	299	Whole Uneviscerated	Lab Duplicate	< 0.30	< 0.25	11

Site: TC-SRBH Spring River @ Blue Hole

Dissolved Oxygen (mg/l)	pH	Specific Conductance (umhos/cm)	Water Temperature (deg C)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Solids, Suspended (mgl/l)	Dissolved Cadmium (ug/l)	Total Cadmium (ug/l)	Dissolved Lead (ug/l)	Total Lead (ug/l)	Dissolved Zinc (ug/l)	Total Zinc (ug/l)	Cadmium, Sediment (mg/kg)	Lead, Sediment (mg/kg)	Zinc, Sediment (mg/kg)
8.20	7.74	220	15.4	77.2	106	46	< 5.0	< 5.0	< 10	< 10	90	186	4	39	754

Species	Mean Length (inches)	Mean Weight (grams)	Sample Preparation	QA Category	Cadmium in Fish (mg/kg)	Lead in Fish (mg/kg)	Zinc in Fish (mg/kg)
Bass, Spotted	7.17	70	Fillet	Sample	< 0.30	< 0.25	8.0
Bass, Spotted	7.58	85	Whole Eviscerated	Sample	< 0.30	< 0.25	33
Bass, Spotted	8.00	105	Whole Uneviscerated	Sample	< 0.30	< 0.25	20
Buffalo, Smallmouth	17.40	1180	Whole Uneviscerated	Sample	< 0.30	2.5	48
Buffalo, Smallmouth	17.40	1180	Whole Uneviscerated	Lab Duplicate	< 0.30	2.1	42
Carp	18.00	1196	Fillet	Sample	< 0.30	< 0.25	16
Carp	19.08	1522	Whole Eviscerated	Sample	< 0.30	1.0	62
Carp	19.92	1762	Whole Uneviscerated	Sample	0.84	1.7	70
Catfish, Channel	14.92	407	Fillet	Sample	< 0.30	< 0.25	3.5
Catfish, Channel	14.92	407	Fillet	Lab Duplicate	< 0.30	< 0.25	4.1
Catfish, Channel	16.08	503	Whole Eviscerated	Sample	< 0.30	R	20
Catfish, Channel	16.92	650	Whole Uneviscerated	Sample	< 0.30	0.88	38

Site: TC-SRMB Spring River @ Mocassin Bend

Dissolved Oxygen (mg/l)	pH	Specific Conductance (umhos/cm)	Water Temperature (deg C)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Solids, Suspended (mgl/l)	Dissolved Cadmium (ug/l)	Total Cadmium (ug/l)	Dissolved Lead (ug/l)	Total Lead (ug/l)	Dissolved Zinc (ug/l)	Total Zinc (ug/l)	Cadmium, Sediment (mg/kg)	Lead, Sediment (mg/kg)	Zinc, Sediment (mg/kg)
7.34	7.86	223	14.0	92.3	119	45	< 5.0	< 5.0	< 10	< 10	73	136	3	53	725

Species	Mean Length (inches)	Mean Weight (grams)	Sample Preparation	QA Category	Cadmium in Fish (mg/kg)	Lead in Fish (mg/kg)	Zinc in Fish (mg/kg)
Bass, White	14.80	746	Whole Uneviscerated	Sample	< 0.30	< 0.25	16
Buffalo, Smallmouth	16.45	1105	Whole Uneviscerated	Sample	< 0.30	0.88	21
Carp	19.33	1584	Fillet	Sample	< 0.30	< 0.25	4.2
Carp	20.08	1763	Whole Eviscerated	Sample	< 0.30	1.9	62
Carp	22.33	2070	Whole Uneviscerated	Sample	0.56	3.5	53
Catfish, Channel	15.88	501	Fillet	Sample	< 0.30	< 0.25	6.7
Catfish, Channel	16.88	660	Whole Eviscerated	Sample	< 0.30	0.50	16
Catfish, Channel	18.13	868	Whole Uneviscerated	Sample	< 0.30	0.42	30
Crappie, White	10.75	294	Fillet	Sample	< 0.30	< 0.25	6.0
Crappie, White	10.75	294	Fillet	Lab Duplicate	< 0.30	< 0.25	5.4
Crappie, White	11.50	379	Whole Eviscerated	Sample	< 0.30	< 0.25	27
Crappie, White	13.31	585	Whole Uneviscerated	Sample	< 0.30	0.26	21
Sunfish, Bluegill	6.05	67	Whole Uneviscerated	Sample	< 0.30	0.57	32

Site: TC-SRTB   Spring River @ Twin Bridges SP

Dissolved Oxygen (mg/l)	pH	Specific Conductance (umhos/cm)	Water Temperature (deg C)	Total Alkalinity (mg/l)	Total Hardness (mg/l)	Solids, Suspended (mgl/l)	Dissolved Cadmium (ug/l)	Total Cadmium (ug/l)	Dissolved Lead (ug/l)	Total Lead (ug/l)	Dissolved Zinc (ug/l)	Total Zinc (ug/l)	Cadmium, Sediment (mg/kg)	Lead, Sediment (mg/kg)	Zinc, Sediment (mg/kg)
6.90	7.85	178.2	16.1	58.0	85.9	54	< 5.0	< 5.0	< 10	< 10	61	115	5	23	507

Species	Mean Length (inches)	Mean Weight (grams)	Sample Preparation	QA Category	Cadmium in Fish (mg/kg)	Lead in Fish (mg/kg)	Zinc in Fish (mg/kg)
Bass, White	15.15	696	Whole Uneviscerated	Sample	< 0.30	< 0.25	23
Bass. large mouth	15.45	1016	Whole Uneviscerated	Sample	< 0.30	< 0.25	9.8
Buffalo, Smallmouth	17.45	1349	Whole Uneviscerated	Sample	< 0.30	0.95	19
Carp	18.19	1273	Fillet	Sample	< 0.30	< 0.25	10
Carp	18.75	1362	Whole Eviscerated	Sample	< 0.30	1.8	55
Carp	20.00	1568	Whole Uneviscerated	Sample	0.30	1.9	53
Catfish, Channel	13.17	272	Fillet	Sample	< 0.30	< 0.25	6.7
Catfish, Channel	13.17	272	Fillet	Lab Duplicate	< 0.30	< 0.25	4.8
Catfish, Channel	13.50	308	Whole Eviscerated	Sample	< 0.30	< 0.25	10
Catfish, Channel	16.08	558	Whole Uneviscerated	Sample	< 0.30	0.33	20
Crappie, White	10.45	265	Fillet	Sample	< 0.30	< 0.25	5.4
Crappie, White	10.85	317	Whole Eviscerated	Sample	< 0.30	< 0.25	8.1
Crappie, White	11.65	399	Whole Uneviscerated	Sample	< 0.30	< 0.25	14
Sunfish, Bluegill	5.25	42	Fillet	Sample	< 0.30	< 0.25	8.3
Sunfish, Bluegill	5.08	37	Fillet	Field Replicate	< 0.30	< 0.25	7.2
Sunfish, Bluegill	5.08	37	Fillet	Lab Duplicate	< 0.30	< 0.25	7.9
Sunfish, Bluegill	5.50	50	Whole Eviscerated	Field Replicate	< 0.30	< 0.25	23
Sunfish, Bluegill	6.00	65	Whole Eviscerated	Sample	< 0.30	0.25	25

Site: TC-SRTB Spring River @ Twin Bridges SP (cont.)

Species	Mean Length (inches)	Mean Weight (grams)	Sample Preparation	QA Category	Cadmium in Fish (mg/kg)	Lead in Fish (mg/kg)	Zinc in Fish (mg/kg)
Sunfish, Bluegill	6.75	98	Whole Uneviscerated	Sample	< 0.30	< 0.25	17
Sunfish, Bluegill	6.25	80	Whole Uneviscerated	Field Replicate	< 0.30	0.27	19