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Tar Creek, Oklahoma

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SITE SPECIFIC WATER QUALITY ASSESSMENT: TAR CREEK, OKLAHOMA

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ENVIRONMENTAL MONITORING SYSTEMS LABORATORY
OFFICE OF RESEARCH AND DEVELOPMENT
U.S. ENVIRONMENTAL PROTECTION AGENCY
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I INTRODUCTION

Increasing use of metals in manufacturing and chemical industries has caused a measurable rise in ambient toxic metal concentrations in industrial discharges (Spaulding and Ogden 1968). As a result, many of our nation's receiving surface waters contain elevated levels of metals. Primary sources of most toxic metals include industrial and municipal sewage treatment plant (publicly owned treatment works) discharges, mine drainage, and atmospheric precipitation (Spaulding and Ogden 1968; EPA 1979a).

Effluent and sludge of many publicly owned treatment works (POTWs) are known to contain high metal concentrations (Dewalle and Chian 1980). This has been assumed to result from industrial wastewater discharges to POTWs. However, high metal concentrations have also been found in POTWs which do not receive industrial wastes.

Results from recent sampling of a wide spectrum of POTW effluents (U.S. Geological survey data; Sverdrup and Parcel and Associates, Inc. 1977; Dewalle and Chian 1980) showed that the concentration of several toxic metals in receiving streams exceeded freshwater aquatic life criteria recommended by the U.S. Environmental Protection Agency (U.S. EPA 1976). In many cases, levels were of sufficient magnitude to suggest that the biological communities of many of the nation's surface waters could be experiencing severe impacts. However, undocumented reports have claimed that substantial populations of aquatic life (fish, invertebrates, plants) exist in a healthy condition in waters containing concentrations in excess of the recommended criteria.

Prompted by this apparent contradiction the EPA Office of Water Regulations and Standards (OWRS) issued a directive to document the water and biological quality that exist in selected streams receiving POTW discharges. Later, as other important sources of metals were identified, the program was expanded to include the investigation of mining and industrial discharges. The toxic metals program was based on the following study objectives:

1. To document the concentration and distribution of toxic metals in selected streams receiving discharges from publicly owned treatment works (POTWs), mining, and industrial wastes.

2. To determine the biological state of receiving waters when the aquatic life criteria for toxic metals are exceeded. This included sampling and analyzing fish, benthic invertebrates, and periphyton communities.

3. To report the extent to which criteria levels were observed to be exceeded.

4. To develop explanatory hypotheses when healthy biota exist where criteria are exceeded.

The project was undertaken as a cooperative effort by EPA's Environmental Monitoring Systems Laboratory, Las Vegas, Nevada (EMSL-LV) and the Environmental Research Laboratories at Corvallis, Oregon (ERL-Corvallis) and Duluth, Minnesota (ERL-Duluth). EMSL-LV designed the project and supervised the field investigation in cooperation with University of Nevada, Las Vegas (UNLV) personnel. Laboratories at ERL-Duluth and ERL-Corvallis performed static bioassay tests to assess the toxicity of whole and filtered water samples from each stream investigated.

From a list of approximately 200 candidate streams, 50 were selected for a preliminary field survey. The list was then narrowed to 15 streams (Table 1) which received mining, industrial, or municipal discharges. Streams were selected to provide broad geographical representation and a range of watershed characteristics and uses, pollution sources, water quality characteristics, biota, and habitats. Field sampling for biological, physical, and chemical water quality information was conducted from July 28 to November 10, 1980. Figure 1 illustrates the general approach to each study site. In each river, a control site was sampled upstream from a discharge point, and transects were established downstream from the discharge to define impact and subsequent recovery zones.

Individual study sites were chosen according to the following criteria:

1. Toxic metal concentrations upstream from effluent discharges were below current water quality criteria.

2. Metal concentrations in receiving waters after complete mixing with effluent discharge were 5 to 10 times greater than the water quality criteria.

Data from the 1980 toxic metals project will be presented in 15 separate reports discussing each river system; a summary project report will follow the individual basin studies. This report addresses data collected in Tar Creek, Oklahoma.

STUDY AREA

Tar Creek is a small, ephemeral stream located at the Kansas-Oklahoma border that receives runoff from abandoned zinc and lead mines in the Picher field. In 1918, approximately 230 interconnected mines existed; between 400-900 open or partially collapsed shafts are presently scattered throughout Ottawa County, Oklahoma, many of which are concealed (Adams 1980; Parrish unpublished data). These abandoned mines began discharging highly mineralized water into Tar Creek during November 1979 as a result of the rising groundwater table in northeast Oklahoma.

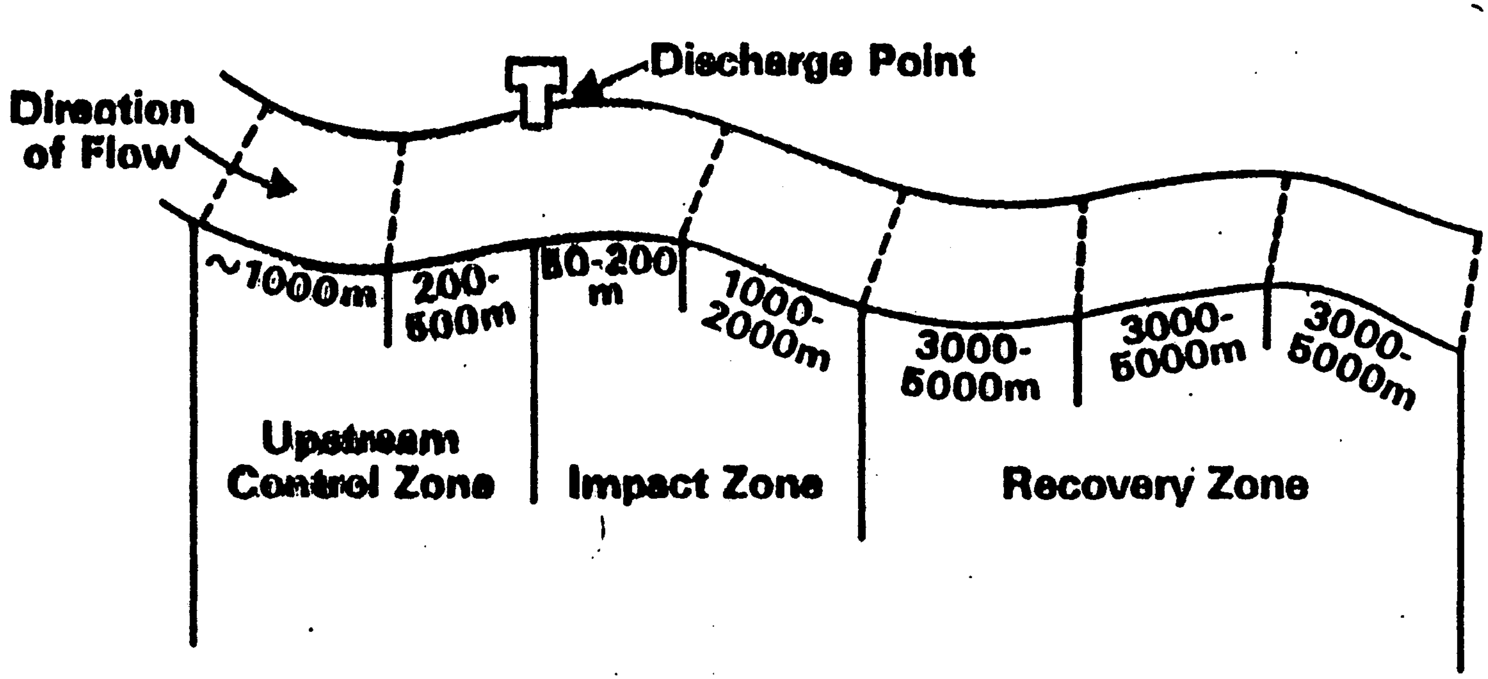
Although the headwaters of Tar Creek originate in Kansas, water rarely flows across the Oklahoma border except during wet periods when more than 5 cm precipitation falls on the upper Tar Creek watershed (Anonymous 1981). The creek is generally characterized by standing pools with no measurable current and a sandy-silty substrate. Temporary stream runoff between pools seasonally occurs as a result of overflowing seepage from chat piles. The ephemeral

TABLE 1. 1980 STUDY LOCATIONS, TYPES OF DISCHARGES, AND METALS PRESENT IN EXCESS OF EPA RECOMMENDED AQUATIC LIFE CRITERIA*

Pollution Source Stream	Metal(s)
<u>Mining</u>	
Prickly Pear Creek, Montana	Copper, Zinc, Cadmium
Silver Bow Creek, Montana**	Copper, Cadmium, Zinc
Slate River, Colorado	Copper, Zinc, Silver, Cadmium
Tar Creek, Oklahoma	Zinc, Cadmium, Silver, Lead
Red River, New Mexico	Copper, Cadmium
<u>Industrial</u>	
Leon Creek, Texas	Chromium, Nickel
Little Mississinewa River, Indiana	Lead, Chromium
<u>Public Owned Treatment Works (POTW)</u>	
Bird Creek, Oklahoma	Arsenic, Slenium
Cedar Creek, Georgia	Chromium, Silver
Maple Creek, South Carolina	Chromium
Irwin Creek, North Carolina	Chromium, Zinc, Nickel, Lead
Blackstone River, Massachusetts	Cadmium, Lead
Mill River, Ohio	Nickel
Cayadutta Creek, New York	Chromium, Cadmium
White River, Indiana	Copper

* In most cases the acute criteria were exceeded (U.S. EPA 1976); chronic criteria were exceeded in all cases.
** Also receives POTW discharges.

Typical Study Site



Each transect consists of:

- 5 replicates for biological samples
- Electrofishing 100 meters of stream reach
- 3 replicates for tissue, sediment and water samples
- 1 twenty-four hour composite water sample
- 8 three hour integrated water samples

Total number of samples per transect

= 37
\+ 45 hydrolab measurements (9 parameters x 5 replicates)

Figure 1. Generalized diagram of the field sampling approach.

streams created by this seepage were not sampled for chemical information during this study. Field biologists, however, report Tar Creek is lined throughout with precipitated ferric hydroxide, a red stain also visible on the lateral stream beds reflecting past water flow.

II METHODS

Five sampling stations were established in Tar Creek (Figure 2) and sampled from October 29 to November 1, 1980. All stations receive runoff from abandoned mines in the Picher field. Therefore, no samples were collected in a true control or recovery zone. These data represent conditions during the time interval sampled and may not be fully indicative of conditions at other time periods. Detailed discussions of the various sampling methodologies follow:

CHEMICAL

Water

Field Collection

To determine the water quality characteristics of Tar Creek, horizontal and vertical profiles of pH, conductivity, temperature, dissolved oxygen (DO), and reduction/oxidation (redox) potential were measured at each station with a Hydrolab 4041 water quality measurement system. Other field measurements included: turbidity with a Hach nephelometer, and chlorine with a Hach field chlorine kit. Triplicate grab samples were collected at each site mid-depth between surface and bottom, preserved appropriately for each analysis as specified in U.S. EPA (1979b) and APHA (1980), and shipped to EMSL-LV for analysis. Filtering of grab samples (0.45 μm filter) for total and dissolved metal fractions analysis was completed on site within approximately three hours of the time of collection. All samples were acidified with Ultrex nitric acid to a pH of <2.0, and shipped to UCLA's Laboratory of Biomedical and Environmental Science for ICAP analysis. In addition to the manual grabs an ISCO sampler collected 24-hour composite samples at one hour intervals for metal analyses. Three one-hour samples of 100 ml each were composited in a 450 ml sample vessel; thus, eight three-hour composite samples were collected at each station. Samples were acidified with Ultrex nitric acid and shipped to UCLA for ICAP analysis.

Laboratory Analysis

Table 2 lists the parameters and methods used for laboratory analyses of water quality in Tar Creek.

Sediments

Field Collection

Streambed sediments were collected in Tar Creek to determine the extent to which metals entering from abandoned mines in the Picher field accumulate in sediments. Backwater pool areas at each station were sampled. Sediment cores were collected with a WILDCO 2" (5 cm) brass core sampler fitted with a plastic core liner and egg shell core catcher. A series of shallow sediment core samples was collected from the submerged root zone along the stream bank. When necessary, several shallow core samples were collected to fill one core

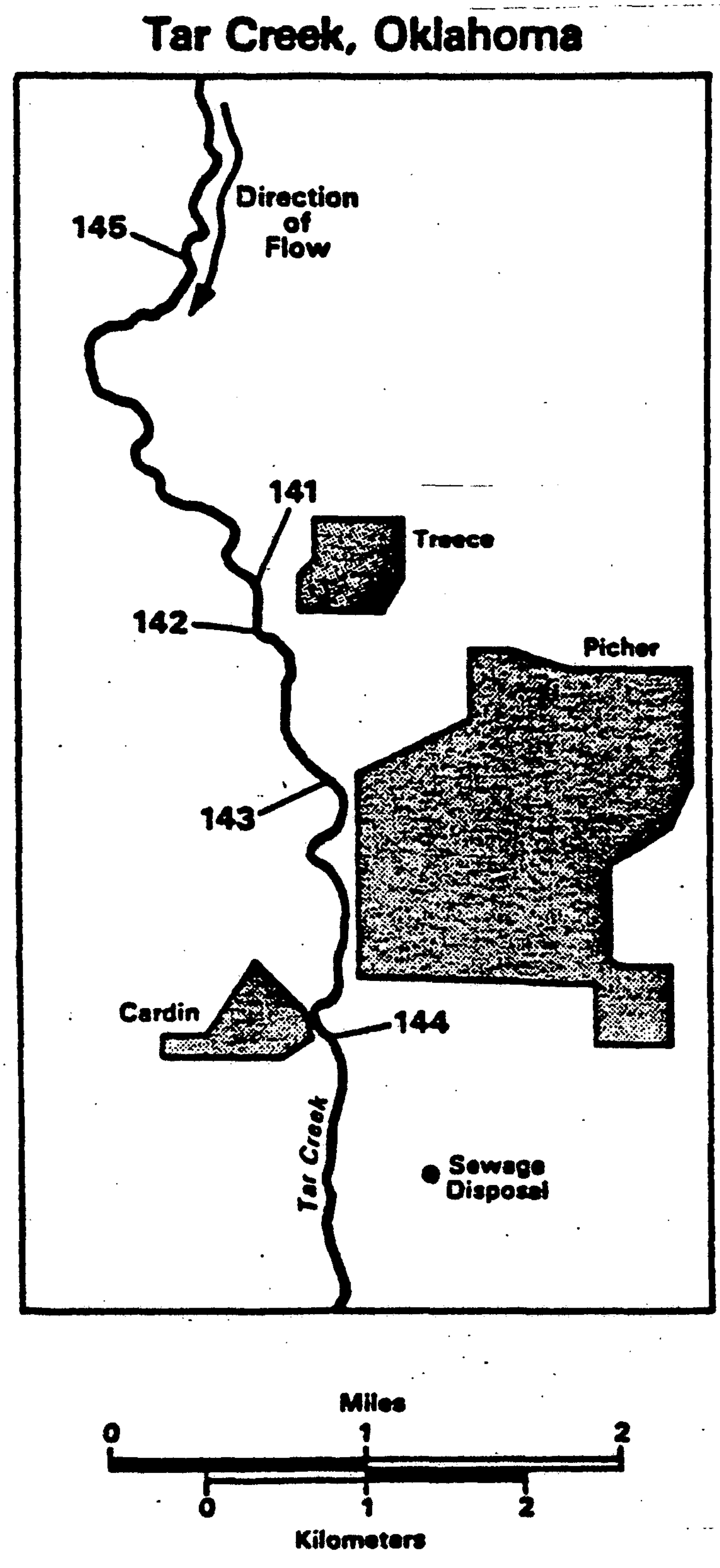


Figure 2. Station locations on Tar Creek, Oklahoma.

TABLE 2. LABORATORY CHEMICAL ANALYSIS OF STREAM WATER QUALITY PARAMETERS

	Parameter	Reference
A.	Automated Analyses (Technicon Auto Analyzer; all values in mg/l)	
	Total phosphate	U.S. EPA 1979b Method 365.1
	Ortho phosphate	U.S. EPA 1979b Method 365.1
	Hydrolysable phosphate	U.S. EPA 1979b Method 365.1
	Kjeldahl nitrogen	U.S. EPA 1979b Method 351.1
	Total Ammonia (NH_4)	U.S. EPA 1979b Method 350.1
	Nitrates + nitrites	U.S. EPA 1979b Method 353.1
	Total alkalinity	U.S. EPA 1979b Method 310.2
B.	Additional Parameters (mg/l)	Reference
	Total Ca + Mg hardness*	APHA (1980) p. 195
	Total organic carbon (carbon analyzer)	U.S. EPA 1979b Method 415.1
	Total residues	U.S. EPA 1979b Method 160.3
	Suspended residues	U.S. EPA 1979b Method 160.1
	Total sulfate	U.S. EPA 1979b Method 375.1
	Total cyanide	U.S. EPA 1979b Method 335.2
C.	Metals - ICAP** Cu, Cd, Zn, As, Ni, Ag, Cr, Se, Ca, Mg, Al, Pb (μg/l)	Alexander and McAnulty 1981
	Total recoverable	U.S. EPA 1979b
	Filtered through 0.45 μm	U.S. EPA 1979b
Composite samples from mixing zone (ISCO) (metal analyses: ICAP μg/l)		Alexander and McAnulty 1981

* Calculations from measured Ca and Mg concentrations.
** ICAP = Inductively Coupled Argon Plasma emission spectroscopy.

tube replicate. Three replicate core samples were collected from each of the five stations and shipped to EMSL-LV for preparation prior to ICAP analyses.

Laboratory Analysis

It has long been known that different particle sizes have different affinities for metals and other positive ions (Namminga and Wihlm 1977; McDuffie et al. 1976), and that the most important particle sizes known to sorb positive ions range from fine sand down to clay. For this reason preliminary tests were conducted in the laboratory prior to final sediment analyses to determine the particle size range sorbing the most metals and expressing the least among replicate variability. Whole samples and 100, 250, and 400 mesh seived sub-samples from Prickly Pear Creek, Montana, sediments were previously analyzed for total recoverable metal (EPA 1981). Based on this experiment, 400 mesh (64 μm) particle sizes contained the most metal per gram sample and exhibited the least replicate variation.

Replicate core samples from Tar Creek were shipped to EMSL-LV, oven dried at 100°C to complete dryness, and sieved through a 400 mesh (64 μm) stainless steel sieve. Each sample was then divided into four equal portions. A 1-gram aliquot was then used for the acid extraction. An extraction medium of 5 mls of HCl and 0.5 mls H_2SO_4 in 50 mls of water was found to be the most effective extraction solvent (EPA 1981). These solution aliquots were then placed in 20 dram scintillation vials and sent to UCLA for ICAP analyses (Alexander and McAnulty 1981).

BIOLOGICAL

Biological monitoring in Tar Creek met three specific goals:

1. To identify and determine the background distribution of algal, invertebrate, and fish species;

2. To determine if biological communities exhibit measureable changes in relation to distance from point sources; and

3. To determine metal concentrations in plant and fish tissues as an indication of sublethal and potentially lethal impacts to the biota, and to provide insight into the fate of various metals.

Table 3 summarizes the biological parameters measured, collection techniques, and analytical methodologies. A more detailed description of the methods used to sample and analyze each parameter is discussed below.

<u>Macroinvertebrates</u>

Field Collection

The Standardized Traveling Kick Method (STKM) (Pollard and Kinney 1979) was used to collect invertebrate samples in Tar Creek. Three replicates were collected at each site using a 30-mesh triangular dip net with a mouth opening of 25 cm x 25 cm x 25 cm and a length of 76 cm. Kick sampling was standardized by the investigator holding a net in the water in front of him for 30 seconds while traveling approximately 4 meters downstream vigorously kicking the substrate. This sampled an area approximately 0.75 x 4 meters (3 m^2).

After collection, samples were washed through a 30 mesh sieve-bottom

TABLE 3. SUMMARY OF BIOLOGICAL PARAMETERS SAMPLED IN TAR CREEK FROM OCTOBER 29 TO NOVEMBER 1, 1980 AND ASSOCIATED METHODS

Tissue Concentrations of Toxic Metals	Ecological Indicators
Aquatic Macrophytes (Representative species at each station, analyzed by DC arc spectroscopy)	Periphyton (Scrapes from submerged macrophytes, sedges, logs, and branches)
Root tissue	Species identification
Leaves and stems	Relative abundance counts
Fish (Seining, electrofishing, analyzed by DC arc spectroscopy	Invertebrates (Standardized Traveling Kick Method)
Gill	Species identification
Muscle	Relative abundance counts
Liver	
Kidney	Fish (Seining, electrofishing)
Gonad*	
Brain*	Species identification
Eye*	Relative abundance
Whole body**	Length/weight relationships

* Selected individuals from locations with extremely high metal concentrations.

** Whole fish were analyzed in small specimens.

bucket, placed in a white enamel pan, and field-sorted to major taxonomic groups. Field extraction of animals from each sample was checked by another field team member as a quality control measure. This QA check involved scanning the sorting pan until no additional macroinvertebrates were observed for two minutes of continuous scanning. Sorted invertebrates and any unsorted samples were preserved in the field with approximately 10 percent formalin and returned to EMSL-LV for final processing.

Laboratory Analysis

Collected benthic invertebrates were identified to the lowest possible taxonomic level and counted at UNLV. Laboratory quality assurance sorting criteria were the same as for field sorting when additional sorting was required. Some members of the order Diptera were only identified to the subfamily level (e.g., Chironominae) and members of the Oligochaeta were keyed only to class. A reference collection of identified specimens is stored at the lab.

Macroinvertebrate data were compiled and stored in a local PDP 1170 computer system where various mathematical and statistical computations were made. Invertebrate data analyses for Tar Creek consisted of: 1) total number of individuals (standing crop), 2) total number of taxa (species richness), and 3) relative species abundance (percentage data).

Plants

Periphyton

Field Collection

Periphyton was collected from submerged logs, branches, and macrophytes (Table 4). Sections of the submerged substrates were scraped with a razor blade. Due to the wide variety of substrate types, no attempt was made to quantify the size of the area sampled. Each of the three replicates was adjusted to a standard volume by adding distilled water. Acid-lugols preservative was added to each sample to produce a final concentration of 1-5 percent (V/V) depending on the algal biomass present.

Laboratory Analysis

Counting and identification procedures included two analysis steps: a) one subsample was acid-cleaned for diatom species identifications and proportional counts, and b) the second subsample was examined with an inverted microscope to count and identify non-diatoms (greens, blue-greens, euglenoids, cryptomonads, crysophtyes, and dinoflagellates).

A. Diatom Proportional Count

One 10-20 ml sub-sample was removed with a wide-bore pipette and placed in a 25 ml Erlenmeyer flask to which five ml of concentrated nitric acid (HNO_3) was then added. Flasks were placed on a heating plate inside a fume hood, and samples were mildly boiled for approximately 5 minutes or until sample color became clear. This procedure oxidized sample organic material and broke up gelatinous material, leaving the silica diatom frustules. Each subsample was then centrifuged for 5 minutes. The supernatant was decanted and the centrifuge tube refilled with distilled water. This procedure was repeated two additional times to remove any remaining HNO_3. After final centrifugation, one or two drops of concentrated sample were placed on a cover glass and mounted with Hyrax™ mounting media. The edge of the slide was sealed with clear fingernail polish.

TABLE 4. TYPES OF SUBSTRATES SAMPLED FOR PERIPHYTON AT TAR CREEK, OKLAHOMA

Station	Type of Substrate Scraped
145	Submerged logs and branches
141	Macrophytes (_Typha_ sp.)
142	Sedges (_Scirpus_ sp.)
143	Macrophytes (_Typha_ sp.)
144	Macrophytes (_Typha_ sp.) and grasses (Graminaceae)

Counting Procedure

Diatoms were identified and counted at 1000X magnification (oil emersion) with an Olympus BHT phase contrast microscope. Random strips were scanned until at least 300 diatom cells were counted and identified (Weitzel 1979). Samples with less than 300 cells present were scanned for one hour since long counts of 5000-10000 diatoms or more, such as are recommended by Patrick (1977), are far too time consuming for most water quality studies. Counting fewer diatoms (300) provides reliable results (Weber 1973) and compares well with longer counts of 1000 diatom frustules (Castenholtz 1960).

B. Non-Diatom Count

A 0.05 to 2.0 ml subsample was introduced into a Wild™ plate chamber. Strips were scanned across the entire counting chamber diameter under 100-400X magnification using an Olympus IMT inverted microscope. All non-diatoms were counted and identified during this step as well as total viable diatom frustule number. If excess clumping was evident, the sample was placed in a "sonifier" unit to break up clumps and filaments.

<u>Macrophyte Tissues</u>

Field Collection

Macrophytes from the family Graminacea were collected for tissue analysis from banks where the root zone was in contact with stream water. Random samples from the whole plant (leaves, stems, and roots) were collected in triplicate from each station. These samples were frozen and shipped to EMSL-LV with dry ice.

Laboratory Analysis

Macrophyte samples were thawed, roots and stems were separated at the soil surface level, and each of the parts was washed three times in distilled water. Each washing consisted of placing the sample in a 16 oz nalgene bottle, filling to 1/3 volume, and agitating for one minute. All plant samples were oven dried at 80°C to complete dryness, placed in plastic 20 dram vials, and homogenized with a Model 8000 Mixer Mill (Spex Industries Inc.). Approximately 1 gm aliquots were then placed in 20 dram scintillation vials and sent to UCLA for analysis by DC Arc Spectrometry (Alexander and McAnulty 1981).

Fish

Community Census

Fish samples taken in this study were qualitative collections with emphasis placed on presence or absence of various fish species upstream and downstream from the primary discharge. Sampling was conducted by electrofishing with a backpack shocker. All fish were identified, weighed, and measured in the field.

Tissues

Field Collection

Mature sunfish (*Lepomis* spp.) were collected from each station where available; each was frozen, and shipped with dry ice to EMSL-LV. The fish were later thawed; liver, gill, muscle, and kidney tissues were dissected from each fish. Brain, gonad, and eye tissues were also extracted to compare metal accumulation in various tissues.

Laboratory Analysis

Triplicate samples of approximately 1 gm from each tissue type were freeze dried and sent to UCLA's Laboratory of Biomedical and Environmental Science for DC Arc Spectrometry analysis (Alexander and McAnulty 1981). At UCLA each of 3 aliquots was individually weighed and analyzed for metal content.

Bioassays

Field Collection

Water samples from stations 142 and 143 were collected in 5 gallon cubitainers, packed in ice, and shipped to ERL-Duluth for bioassay.

Laboratory Analysis

Bioassays were conducted on whole water samples. The Duluth work consisted of experiments on: 1) an activity index of bluegill sunfish (*Lepomis macrochirus*); 2) acute toxicity to *Daphnia magna*; 3) immobilized enzymes; and 4) chlorophyll *a* fluorescence.

III RESULTS AND DISCUSSION

CHEMICAL

Water Quality

Several publications have identified some water quality parameters which may alter metal toxicity in controlled laboratory bioassays (Lloyd and Herbert 1962; Nishikowa and Tabata 1969; Brown et al. 1974; Shaw and Brown 1974; Waiwood and Beamish 1978; Howarth and Sprague 1979; and Miller and Mackay 1980). These factors include hardness, alkalinity, pH, temperature, and turbidity from dissolved or particulate matter. An attempt was made to accurately characterize water quality in Tar Creek by identifying and quantifying as many parameters as feasible (Appendix A). Metal data from both mid-depth grab samples and ISCO 24-hour automatic collections are included in the Appendix.

Water samples were analyzed for total and dissolved metal concentrations and compared to EPA (1980) recommended acute criteria for aquatic life (Table 5). Ambient total and dissolved metal concentrations were also compared for key metals at all stations in Tar Creek (Table 6). The data show elevated concentrations of metals throughout the creek. However, because of extremely high water hardness (Ca+Mg), only zinc and cadmium exceeded recommended criteria values. Metal concentrations at Station 141 were typically one-half those at the upstream site (145), but then increased again at Station 142, presumably due to mining runoff entering Tar Creek between the two sites. For most key metals examined, concentrations continued to increase at the further downstream stations (143 and 144) in the vicinity of Picher and Cardin.

It should be noted that in some cases, mean dissolved metal concentrations apparently exceed mean total metals (Table 6). This anomaly generally occurs: 1) when metal concentrations, such as arsenic, are near instrument detection limits; or 2) when confidence intervals around dissolved and total metal means are overlapping, indicating there is no significant ($p=0.05$) difference between them. An unexplained exception to this occurs at Station 144, where dissolved lead, nickel, silver, and arsenic mean concentrations appear to be double the mean totals for these metals. The total zinc mean value was reported as double the dissolved. Total and dissolved metals throughout all other stations in Tar Creek are quite similar. Since no striking differences in general water quality parameters (e.g., residues, pH, etc.) between Station 143 and 144 were observed, these anomalous data at Station 144 are outliers and may be suspect. For the key metals examined, with the exception of arsenic, an extremely high percentage (70-100%) of total metal concentrations in Tar Creek occurs in the dissolved fraction, with a much smaller fraction sorbed or chelated by suspended particulate matter. Comparisons of nonfiltrable and total residue values also indicate a low level of suspended particulate matter.

Except for the high chlorine and hardness values, levels of the other general water quality parameters (Appendix A) are within the normal range of natural streams. Reported chlorine values, however, are extremely high, ranging to more than two orders of magnitude above EPA recommended criteria.

TABLE 5. COMPARISON OF MEAN TOTAL CONCENTRATIONS OF SELECTED METALS VERSUS CALCULATED ACUTE WATER QUALITY CRITERIA (U.S. EPA 1980) FOR AQUATIC LIFE. Mean values based on grab and ISCO samples combined.

	Stations				
	145	141	142	143	144
Hardness (mg/l)	451	903	1205	1030	1166
Metal (μg/l)					
Total Cadmium					
Actual ($\bar{x}$)*	110	32	122	167	84
Criterion	15	40	35	41	30
Total Lead					
Actual ($\bar{x}$)	439	283	266	333	591
Criterion	1083	3447	2962	3585	2521
Total Zinc					
Actual ($\bar{x}$)	27527	10650	27462	40628	30169
Criterion	1122	2468	2226	2535	1995
Total Nickel					
Actual ($\bar{x}$)	124	63	98	116	171
Criterion	300	618	562	634	509
Total Silver					
Actual ($\bar{x}$)	128	37	43	73	180
Criterion	54	278	224	293	179
Total Arsenic					
Actual ($\bar{x}$)	208	109	117	76	283
Criterion	440	440	440	440	440

* Means represent three or more analytical replicates unless otherwise indicated.

TABLE 6. MEAN TOTAL AND DISSOLVED CONCENTRATIONS OF SELECTED METALS (μg/l), GRAB SAMPLES ONLY, AT EACH STATION IN TAR CREEK, OKLAHOMA. Numbers enclosed in parentheses are 95% confidence intervals*.

	Station 145	Station 141	Station 142	Station 143	Station 144
Cadmium (Detection Limit = 7.5)					
Total	113.2 (9.3)	32.5 (2.6)	122.1 (1.2)	278.3 (4.0)	88.6 (1.7)
Dissolved	108.7 (2.2)	27.0 (2.2)	117.7 (4.3)	277.3 (3.0)	85.2 (2.0)
% Dissolved	96	83	96	100	96
Lead (Detection Limit = 120)					
Total	531.2 (70.3)	282.9 (27.6)	266.2 (14.0)	285.8 (44.1)	309.2 (20.4)
Dissolved	421.8 (33.7)	205.9 (34.1)	197.8 (48.6)	240.0 (21.7)	644.3 (18.6)
% Dissolved	79	73	74	84	100
Zinc (Detection Limit = 9)					
Total	24900.0 (1401.1)	10266.7 (85.9)	27462.5 (532.0)	38033.3 (467.5)	41750.0 (618.0)
Dissolved	25433.3 (343.0)	10650.0 (109.8)	27666.7 (764.9)	38050.0 (268.5)	27283.3 (691.2)
% Dissolved	100	100	100	100	65
Nickel (Detection Limit = 9)					
Total	151.7 (20.7)	63.2 (18.0)	98.5 (9.5)	113.7 (11.0)	106.3 (21.5)
Dissolved	128.0 (10.5)	53.5 (20.6)	72.5 (11.1)	89.7 (10.8)	209.3 (22.8)
% Dissolved	84	85	74	79	100
Silver (Detection Limit = 12)					
Total	151.3 (41.5)	37.0 (11.5)	43.4 (6.7)	45.8 10.1)	108.5 (14.4)
Dissolved	117.7 (10.4)	30.7 (4.7)	23.3 (12.0)	50.7 (10.4)	189.0 (17.5)
% Dissolved	78	83	54	100	100
Arsenic (Detection Limit = 110)					
Total	328.0 (100.1)	108.7 (74.8)	116.6 (57.0)	77.5 (54.4)	105.4 (58.6)
Dissolved	185.2 (82.6)	31.0** (63.8)	16.0** (50.3)	84.5 (65.1)	370.0 (45.3)
% Dissolved	56	28	14	100	100

* Confidence intervals that overlap indicate total and dissolved metal mean concentrations are not significantly (p = 0.05) different.

** [illegible] 2 samples [illegible]

These high values may be attributable to field measurement techniques rather than actual elevated chlorine values in the area. This methodology is currently being reevaluated at EMSL-Las Vegas by comparisons of data using a Hach chemical kit and Standard EPA Chemical Procedures (EPA 1979b).

Analysis of variance (ANOVA) and Bartlett's test for homogeneity of variances were performed to test for significant differences between stations, field replicates, and laboratory analytical replicates for six ambient total metals in Tar Creek. For two of these metals (zinc and cadmium), ANOVA parametric assumptions for normality and heterogeneity of variances were unable to be met (indicated by Bartlett's test), so a Kruskal-Wallis ANOVA by ranks (Siegel 1956) was used to test for significant (p=0.05) differences in metal concentrations and the Student-Newman-Keuls (SNK) stepwise multiple range test was calculated (Sokal and Rohlf 1981) to determine between which of the six stations differences occurred. Lead was the only metal for which no significant differences between stations were statistically demonstrated (Table 7).

Although all metals except lead showed significant between-station differences, the SNK tests for these metals did not show consistent up-to downstream patterns of distribution. Cadmium and zinc concentrations at all five stations were statistically separate. Arsenic, nickel, and silver concentrations were significantly (p=0.05) higher at Station 145 than at the other sites, with the downstream sites grouped together. Results of two-way nested ANOVA run with ambient total nickel and silver data show that the greatest percentage (75-99%) of variability observed in Tar Creek samples can be attributed to between-station differences, rather than analytical or field replicate variation.

Sediments

Analysis of variance and Bartlett's test for homogeneity of variances were performed to test for significant differences in seven metals in sediment samples from all stations in Tar Creek (Table 8). In the case of zinc, a Kruskal-Wallis ANOVA by ranks was used to test for significant differences. When ANOVA F-ratios indicated significant differences (p=0.05) in metal concentrations, the SNK stepwise multiple range test was calculated to determine between which of the five stations differences occurred (Table 9).

Metal data indicate similar distribution patterns for cadmium, lead, copper, and nickel. For each, the furthest upstream station (145) had significantly lower sediment metal concentrations than did the downstream sites. The four downstream stations were generally not significantly different from one another, although copper concentrations were higher at Station 144 than at the upstream stations (Table 9). An SNK test was not run using zinc data.

Mean chromium concentrations were significantly higher at Station 141 than at the other four up- and downstream sites. Arsenic was also fairly homogenous throughout the river. The SNK test indicates that, of the seven metals analyzed in Tar Creek sediments, only chromium was reduced to levels at the most downstream site (144) comparable to those found furthest upstream (145).

In general, Tar Creek sediments are characterized by extremely high metal concentrations. This is consistent with the elevated metal concentrations

TABLE 7. SIGNIFICANCE LEVELS OF BARTLETT'S TEST, ANOVA F-RATIOS, AND KRUSKAL-WALLIS ANOVA BY RANKS FOR TEST OF DIFFERENCES BETWEEN STATIONS FOR AMBIENT WATER METAL CONCENTRATIONS, TAR CREEK, OKLAHOMA.

Metal	Bartlett's	ANOVA	Kruskal-Wallis
Zinc	**		*
Cadmium	**		*
Lead	NS	NS	
Nickel	NS	**	
Silver	NS	**	
Arsenic	NS	**	

* = p=0.01
**= p=0.001

TABLE 8. SIGNIFICANCE LEVELS OF BARTLETT'S TEST, ANOVA F-RATIOS, AND KRUSKAL-WALLIS ANOVA BY RANKS FOR TEST OF DIFFERENCES BETWEEN STATIONS FOR SEDIMENT SAMPLES, TAR CREEK, OKLAHOMA (* = 0.05, ** = 0.01, *** = 0.005, NS = non significant).

Metal	Bartlett's	ANOVA	Kruskal-Wallis
Cadmium	NS		***
Lead	NS		***
Copper	NS		***
Zinc	***		*
Chromium	NS		**
Nickel	NS		***
Arsenic	NS		*

found in water samples. However, an interesting anomaly can be seen when comparing Stations 145 and 141. Metal concentrations in the water column (Table 5) decreased for all metals between 145 and 141 (upstream to downstream), while sediment metal concentrations substantially <u>increased</u>. This was probably attributable to the cessation of surface water discharges from abandoned mine

TABLE 9. STUDENT-NEWMAN-KEULS STEPWISE MULTIPLE RANGE TEST OF TOTAL METAL CONCENTRATIONS IN SEDIMENT SAMPLES, TAR CREEK, OKLAHOMA. NONSIGNIFICANT (p = 0.05) SUBSETS OF GROUP MEANS ARE INDICATED BY HORIZONTAL LINES

	Station				
Metals	145	141	142	143	144
Cadmium					
$\bar{x}$ (mg/kg)	4.1	177.8	70.1	136.6	106.2
SNK					
Lead					
$\bar{x}$ (mg/kg)	40.3	1715.4	1709.2	2780.3	2507.8
SNK					
Copper					
$\bar{x}$ (mg/kg)	7.1	90.2	70.4	46.7	661.0
SNK					
Chromium					
$\bar{x}$ (mg/kg)	11.6	18.7	12.2	12.3	10.4
SNK					
Nickel					
$\bar{x}$ (mg/kg)	4.6	71.1	37.9	28.9	49.3
SNK					
Arsenic					
$\bar{x}$ (mg/kg)	17.8	32.7	50.6	49.3	48.9
SNK					

shafts in the vicinity of Station 141 because of seasonal recession of the local groundwater table. However, there was ample opportunity to accumulate excessive metals in the sediments during periods of active mine discharge. This hypothesis is supported by ferric hydroxide stains in the stream sediments in channels connecting the mine shafts with Tar Creek. It appears that the ephemeral nature of these discharges in the upper Tar Creek watershed causes substantial seasonal variation in stream metal concentrations, and perhaps in the biological communities as well. However, further investigation is needed to verify these trends.

BIOLOGICAL

Macroinvertebrates

There were 19 macroinvertebrate taxa collected in Tar Creek during the 1980 fall sampling effort (Appendix B). Benthic populations were compared at all stations throughout the river (Table 10).

Total combined counts collected in three kick samples increased from three organisms at Station 145 upstream, to 878 organisms at the most downstream site (144). Total number of taxa increased from two species at Station 145 to 11 taxa at Station 143 (Figure 3). Total counts and number of taxa were too low, however, to permit statistical analysis of differences between stations.

Station 145 was the furthest upstream site in Tar Creek. Only one deer fly and two predaceous diving beetles were collected in this isolated pool (Figure 4). The beetle, *Hydrophorus* sp., was not found in samples from any other stations.

Stations 141 and 142 were located 0.4 km apart at the Kansas-Oklahoma state line to the west of Treece. Station 141 was characterized by caddisflies, midges, three species of dragonflies, and two species of damselflies (Figure 4). One dragonfly, *Orthemis ferruginea*, and the caddisfly, *Hydropsyche* sp., were collected only at this station. Field personnel reported mining runoff entering the creek below Station 141; the potential impact of this discharge can be seen by reduced counts and number of taxa at Station 142. The only organisms collected at this site were one aquatic moth and 19 mosquito larvae (*Aedes* sp.).

Standing crop and species richness increased downstream. Three species, *Sialis* sp., *Oxyethira* sp., and *Berosus* sp., were only found at Station 143. Dragonfly, damselfly, and midge taxa found upstream reappeared at this site. Further downstream at Station 144, total count increased substantially. However, 86 percent of this increased count was from oligochaetes and midges (subfamily Chironominae). Neither this subfamily of midges nor any oligochaetes were found at the upstream sites. This striking population shift suggests either a change in substrate or organic input from the nearby community of Cardin. Biting midges (ceratopogonids) and corixid bugs were also collected only at this site.

In Tar Creek, zinc and cadmium concentrations greatly exceed EPA recommended acute water quality criteria at most stations (Figure 5). These recommended criteria are based upon local water hardness. The decrease in dissolved metals at Station 141 correlates (Spearman-Rank $r_s = 0.40$; Siegel 1956) to an increase in standing crop and species richness. Similarly, the metals increase

TABLE 10. DISTRIBUTION OF MACROINVERTEBRATE TAXA, OCTOBER 1980, TAR CREEK, OKLAHOMA

Taxa	Station 145	141	142	143	144
Odonata					
Libellulidae					
Erythemis sp.		x		x	x
Celithemis sp.		x		x	
Orthemis ferruginea		x			
Coengrionidae					
Argia sp.		x		x	
Enallagma/Ischnura complex		x		x	
Megaloptera					
Sialidae					
Sialis sp.				x	
Hemiptera					
Corixidae					x
Trichoptera					
Hydropsychidae					
Hydropsyche sp.		x			
Hydroptilidae					
Oxyethira sp.				x	
Diptera					
Chironomidae					
Chironomini					x
Orthocladiinae		x		x	x
Culicidae					
Aedes sp.			x	x	x
Ceratopogonidae					
Palpomyia group					x
Tabanidae					
Chrysops sp.	X				x
Lepidoptera					
Pyralidae			x		
Coleoptera					
Dytiscidae					
Rhantus/Colymbetes complex				x	x
Hydrophorus sp.	x				
Hydrophilidae					
Berosus sp.				x	
Oligochaeta					x

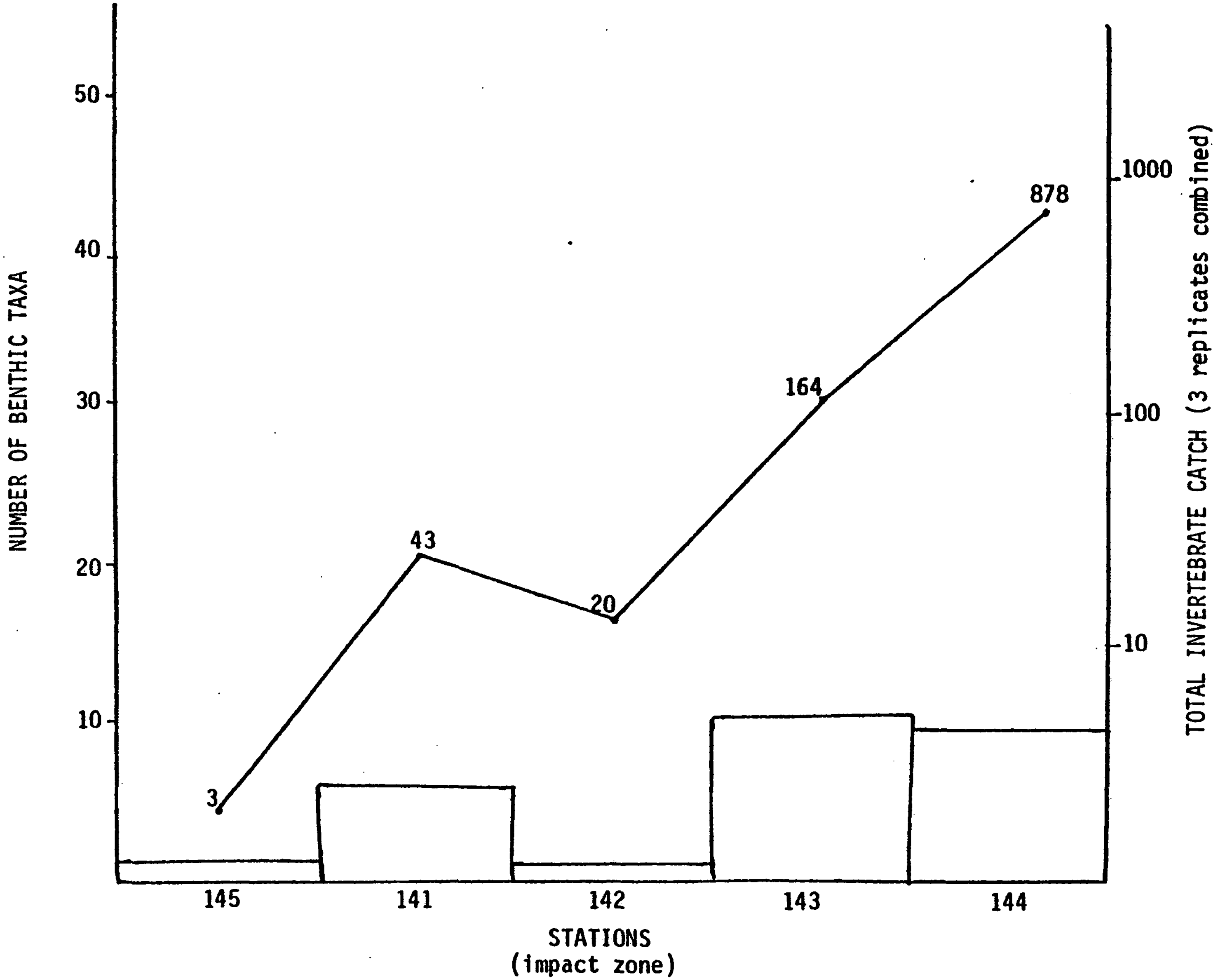


Figure 3. Number of benthic taxa and total invertebrate catch at all stations, Tar Creek, Oklahoma, October 1980.

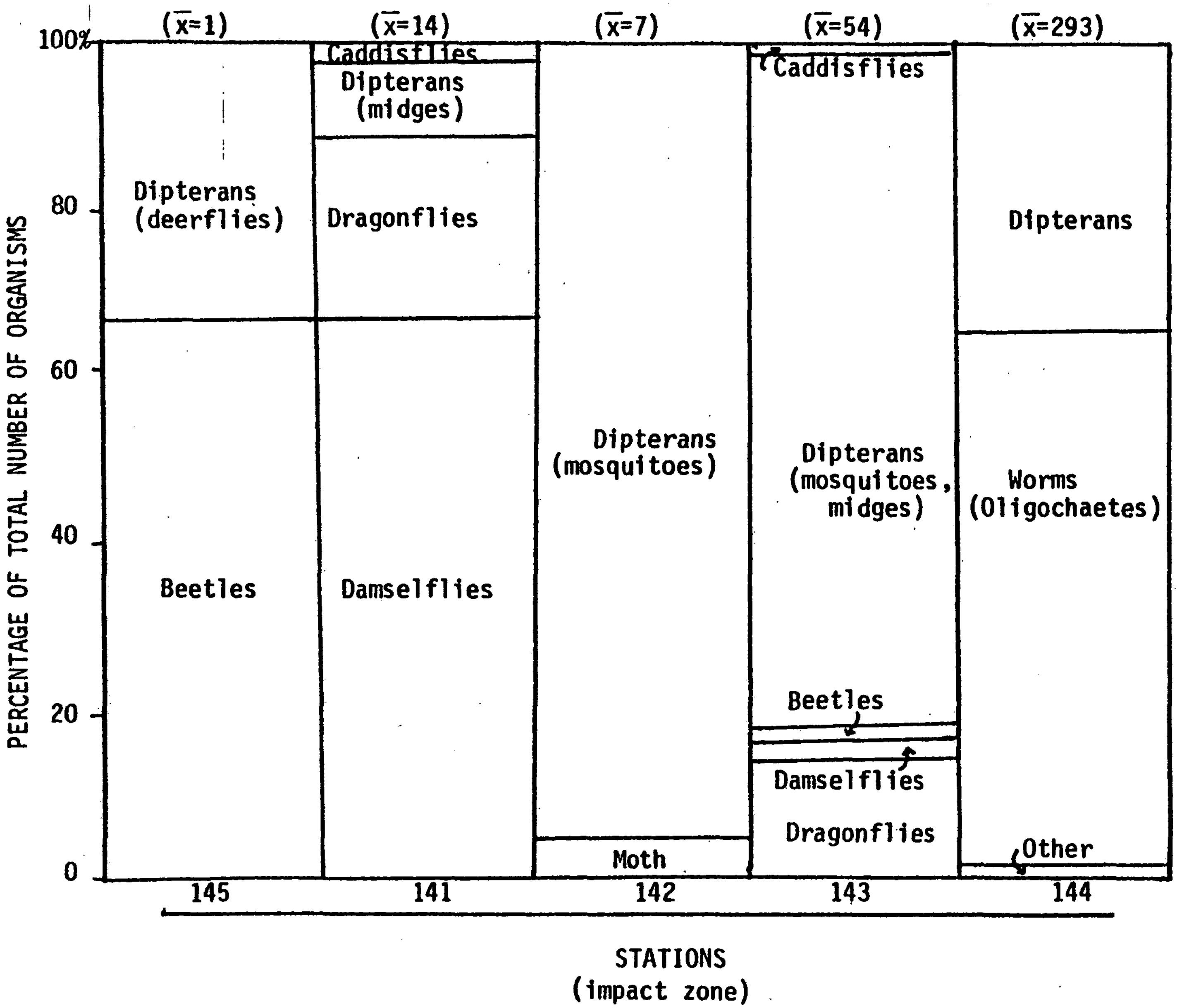


Figure 4. Percent composition of macroinvertebrate groups at stations in Tar Creek, Oklahoma. (Numbers at the top of each station indicate mean organisms count per replicate sample.)

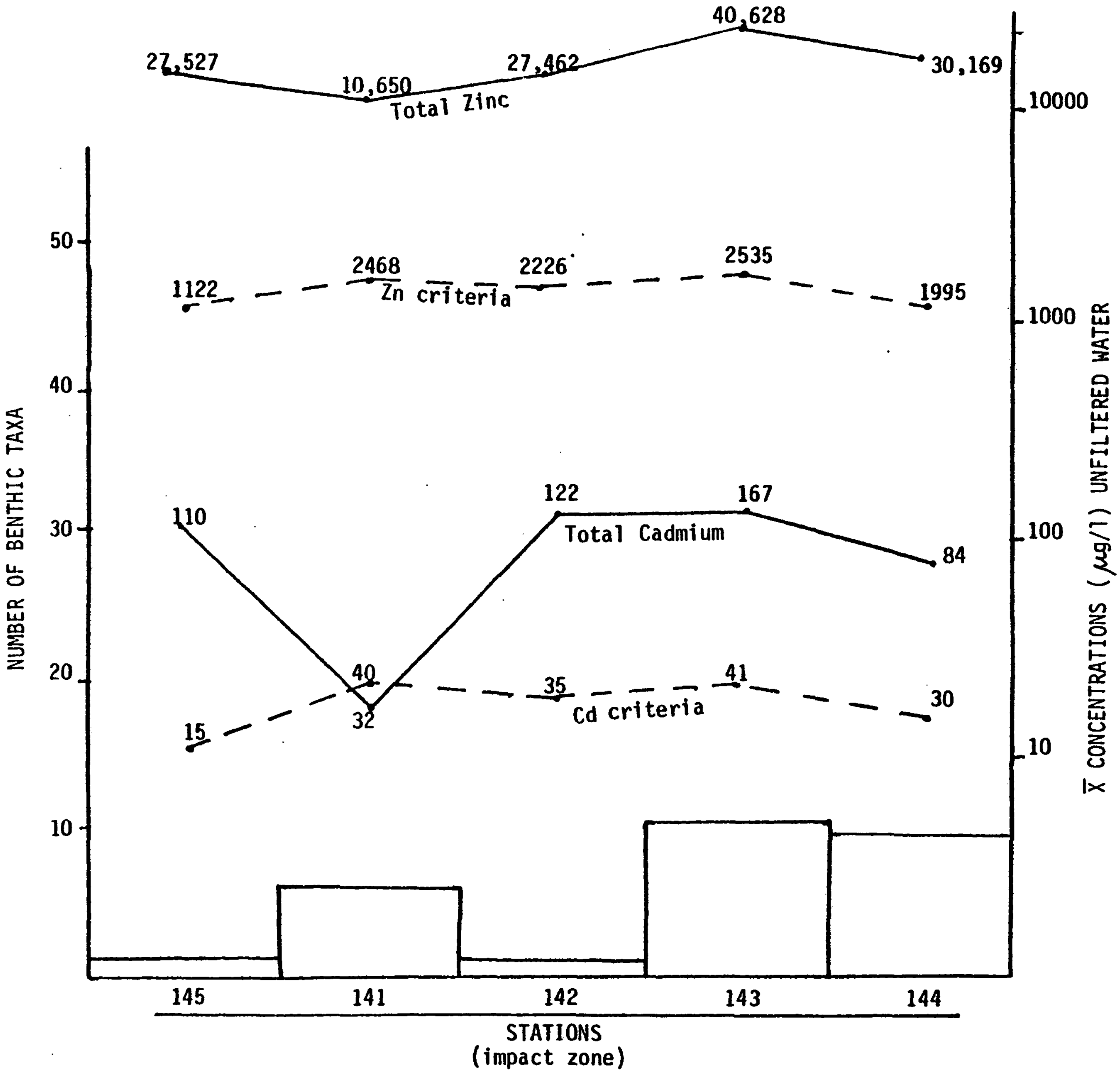


Figure 5. Comparison of species richness in Tar Creek, mean concentrations of total zinc and cadmium, calculated zinc and cadmium water quality criteria.

at Station 142 somewhat corresponds to decreasing counts and number of taxa. However, at Station 143, where the highest metal concentrations were found, the greatest number of taxa and total organisms were collected and counts were higher than at any upstream sites. When metal concentrations decreased at Station 144, total counts increased, although species richness slightly declined. The reasons for these anomalies are unknown.

No control or recovery zone sites were available in Tar Creek, since the entire stream receives runoff from abandoned mines in Kansas and Oklahoma. Thus, additional sampling is needed to define the extent to which macroinvertebrate population patterns are due to metal impacts versus other ecological factors. However, the data suggest that species distributions may largely relate to flow and substrate characteristics of Tar Creek (Table 11). Flow measurements indicated standing water at every station in Tar Creek except at the shoreline of Station 144 where one reading of 6 cm/sec was recorded. Of the 19 invertebrate taxa collected, four are strictly lentic dwellers, nine are generally lentic with some lotic species, and all have some lentic representatives in their group. Most organisms in Tar Creek were not keyed to the species level, so investigation of their specific ecological requirement was limited. Nevertheless, this type of small, slow-moving creek, characterized by isolated ponds and no riffles could be expected to have a homogenous benthic distribution comprised primarily of lentic species. This condition would be expected regardless of the adverse affects of metals. Intuitively, however, a larger standing crop would be expected in a healthy stream than was observed in Tar Creek, and this observed reduction in species relative abundances is most likely due to the impact of metals to the creek.

Actually in view of the extremely high metal concentrations it is remarkable that any form of aquatic life exists in Tar Creek. Increased water hardness (calcium and magnesium salts) decreases the toxicity of many trace metals, including zinc, to aquatic organisms (Skidmore 1964; Mount 1966; Tabata 1969; Salbe 1974; Gregory and Trial 1975; and LaBounty et al. 1975). The high hardness in Tar Creek apparently has a substantial mitigating influence on metal toxicity. This may partially explain observed population patterns in this heavily impacted stream; however, sampling error of such a sparse invertebrate community and subtle habitat differences may also account for the variability among stations. Additional sampling is needed to clarify the causes behind distributional patterns observed in the benthos of Tar Creek.

Plants

Periphyton

The periphyton community is an important component of the biological structure of a stream. Periphyton is defined as the assemblage of plants attached to or found growing on a substrate (Weitzel 1979). Terms used to describe the type of substrate include:

Epilithic - growing on rocks
Epipelic - growing on mud or sediments
Epiphytic - growing on plants
Epizoic - growing on animals
Epidendric - growing on wood
Epipsammic - growing on sand surfaces

TABLE 11. SUMMARY OF HABITAT PREFERENCES FOR MACROINVERTEBRATES COLLECTED IN TAR CREEK, OKLAHOMA (Modified from Merritt and Cummins 1978)

Taxa	Habitat
Libellulidae	
Erythemis sp.	Lentic-littoral (silt in ponds)
Celithemis sp.	Lentic-vascular hydrophytes
Orthemis ferruginea	Lentic-littoral
Coenagrionidae	
Argia sp.	Lotic-erosional (sediments and detritus) and depositional; lentic-erosional and littoral (sediments)
Enallagma/Ischnura	Lentic-vascular hydrophytes; lotic-depositional (vascular hydrophytes)
Sialidae	
Sialis sp.	Lotic-erosional and depositional; lentic-erosional (sediments)
Corixidae	Generally lentic-vascular hydrophytes; lotic-depositional (vascular hydrophytes)
Hydropsychidae	
Hydropsyche sp.	Lotic-erosional, some lentic-erosional
Hydroptilidae	
Oxyethina sp.	Lentic-vascular hydrophytes (with filamentous algae); lotic-erosional and depositional (vascular hydrophytes)
Chironomidae	
Chironomini	Generally lentic-littoral and profundal; lotic-depositional
Orthocladinae	Primarily lotic but with many lentic representatives
Culicidae	
Aedes sp.	Lentic (temporary ponds and pools)
Ceratopogonidae	
Palpomyia group	Lotic-erosional and depositional (detritus); lentic-littoral, profundal, and occasionally limnetic
Tabanidae	
Chrysops sp.	Lentic-littoral; lotic-depositional
Pyralidae	Generally lentic-vascular hydrophytes
Dytiscidae	
Rhantus/Colymbetes	Lentic-vascular hydrophytes; lotic-depositional
Hydrophorus sp.	Lotic-depositional; lentic-vascular hydrophytes
Hydrophilidae	
Berosus sp.	Lentic-littoral; lotic-depositional
Oligochaeta	Lentic; lotic

The periphyton community may contain a vast number of species including diatoms, blue-greens, and green algae. A diatom community may consist of three to four hundred species living together in a relatively small area at any point in time in the benthos of unpolluted streams (Patrick 1978).

Healthy streams usually have high species numbers, each with relatively small populations. A stream perturbation, such as toxic metal pollution, may alter community composition. Change may be expressed in several ways: species richness, number of individuals, or kinds of species. Metal pollution may reduce species diversity and increases total algae abundance, with a few species becoming extremely common (Miller et al. 1982). Shifts in species composition from diatoms to filamentous greens or unicellular greens and blue-green algae have been reported (Patrick 1949). The types of shifts are dependent upon the effects of various kinds of pollution (Patrick 1977).

The diatom community has been isolated as one of the better monitors of water quality and stream conditions (Weitzel 1979). Diatom tolerance to heavy metals include strains ranging from sensitive to very resistant. Metal resistance of only a few algae have been studied both in the laboratory and in the field (Whitton and Say 1975). Results of these studies have not been consistent. For example, a laboratory study of Nitzschia palea (Steemann-Nielsen and Wium-Anderson 1970) indicated that this diatom is very sensitive to soluble copper in the absence of any chelating agent. However, Palmer (1977) included it in a list of tolerant species 'indicative' of copper pollution.

Diatoms are also useful indicators of water quality for the following reasons:

1. With their secure means of attachment to substrates, diatoms may be less subject to drift than invertebrates and are better indicators of conditions at collection locations.

2. A short generation time allows diatoms to better reflect conditions immediately prior to sampling, instead of integrating long-term effects.

3. Diatoms mounts may be stored for many years, permitting re-examination at any later time.

4. Ubiquitous on stream bottoms.

5. Have a wide and well documented range of environmental requirements and pollution tolerances.

6. Easy to collect in sufficient quantity to meet statistical requirements.

Eighty-seven algal taxa were identified in Tar Creek, including 53 diatom taxa (Bacilliariophyceae), 22 greens (Chlorophyta), 5 blue-greens (Cyanophyta), 4 cryptophytes (Cryptophyta), 2 euglenoids (Euglenophyta), 2 chrysophytes (Chrysophyta), and 1 dinoflagellate (Pyrrhophyta) (Appendix C). This assemblage reflects conditions at a single point in time and may not be fully indicative of the composition in all seasons. Periphyton composition and abundance changes under different light, temperature, nutrient, and flow conditions.

This diverse algal assemblage may reflect the wide variety of substrate types sampled (Table 4). No uniform substrate existed at all station locations during the interval sampled from October 29 to November 1, 1980. Therefore, available substrates types were sampled. The lack of similarity between station substrates prevents a detailed statistical comparison of periphyton community composition.

Commonly occurring taxa indicate species may exist under a wide range of environmental conditions and metal concentrations (Table 12).

Forty-six taxa of epidendric algae (growing on wood) were identified at Station 145 (Figure 6, Tables 13 and 14). Diatoms were most abundant, contributing 83% to total relative abundance (Figure 7). The most commonly occurring taxa within this group were Pinnularia subcapitata, Achnanthes minutissima, and Nitzschia ignorata (Table 15). The greens contributed 15% to the total relative abundance, with Hormidium rivilare and Chlorococcum sp. most abundant. H. rivulare has been reported as an "indicator" of high zinc levels in streams (McLean and Jones 1975, Hargreaves and Whitton 1976) (Table 12).

Blue-greens dominated at Station 141, contributing 84% relative abundance (Figure 7), with Lyngbya, Chroococcus, Phormidium, and Oscillatoria the most abundant genera. The greens contributed 11% relative abundance, and Mougeotia was the dominant taxon. Diatoms contributed only 5% to the relative abundance. Blue-greens and greens each contributed 50% relative abundance at Station 142 (Figure 7). Achnanthes minutissima, Anomoeoneis vitrea, and Cymbella minuta var. silesiaca were the most abundant diatoms. Hormidium rivulare and Ulothrix spp. were the common greens (Table 14)).

Greens were the dominant group at Station 143. Chlamydomonas spp., Mougeotia spp. and small monads (flagellates) were the dominants. The cryptophyte, Cyanomonas americana, and the blue-green, Phormidium spp., were also important.

The groups of importance at Station 144 were greens (39%), cryptophytes Cyanomonas americana, and Achnanthes minutissima, respectively.

A summary of the periphyton community in Tar Creek reveals that diatoms were most abundant at Station 145 and 142 and were least important in relative abundance at Station 141 and 143. Hormidium rivulare, which has been reported as an "indicator" of high zinc concentrations, was found in greatest abundance at Stations 145 and 142 at zinc concentrations of 27,000 μg/l (Figure 6). However, it was not important at zinc concentrations greater or less than 27,000 μg/l Zn.

Blue-greens dominated at Station 141 where metal concentrations of 10,650 μg/l Zn and 32 μg/l Cd were lowest of all stations.

The two furthest downstream stations, 143 and 144, were similar in group composition. However, except for the cryptophytes where Cyanomonas americana was common, species composition within groups was quite different.

TABLE 12. REPORTED ENVIRONMENTAL REQUIREMENT, INCLUDING pH RANGE AND HEAVY METAL TOLERANCE OF THE IMPORTANT PERIPHYTON TAXA OBSERVED IN TAR CREEK, OKLAHOMA.

Taxa	Distribution and Environmental Requirements
Achnanthes minutissma	Cosmopolitan; one of the most ubiquitous diatoms known; is the best indicator of high oxygen concentrations in alkaline waters; calcium, and iron indifferent (Lowe 1974). Generally characteristic of unpolluted rivers (Lange-Bertalot 1979 and Besch et al. 1972). pH requirements: range 7-8 (Maillard 1959) optimum 7.5-7.8 (Cholnoky 1968) Heavy metal tolerance: low resistant; tolerant to 0.1-0.2 mg Zn/l (Besch et al. 1972)
Pinnularia subcapitata Greg.	Prefers water of low mineral content (Patrick and Reimer 1966)
Nitzschia ignorata Krasske	"Indicator" of hydrogen sulfide presence (Palmer 1977)
Anomoeoneis vitrea (Grum.) Ross	Cosmospolitan; calcium indifferent (Lowe 1974); adapted to a wide range of ecological conditions (Patrick and Reimer 1966) pH requirements: range 6.2-9.2 optimum 6.7 (Lowe 1974)
Cymbella minuta var. silesiaca (Cymbella ventricosa Kutz.)	Cosmopolitan; oxygen saturation is optimal (Lowe 1974). Widespread and eurytopic (Patrick and Reimer 1966) pH requirements: range 6.2-8.5 (Lowe 1974) optimum under 7.5 Heavy metal tolerance: "indicator" of copper (Palmer 1977)
Hormidium rivulare Kutz	Common alga of acid streams. pH requirements: range 2.5-7.0 optimum 3.5-4.0 (Hargreaves and Whitton 1976) Heavy metal tolerance: tolerant to high levels of Zn (4 mg/l). "Indicator" of heavy metal pollution. (Mclean and Jones 1975). Toxicity of zinc is least at the optimum pH range; toxicity increase markedly at higher pH values (Hargreaves and Whitton 1976)

Continued

TABLE 12. Continued

Taxa	Distribution and Environmental Requirements	
Ulothrix spp	Widely distributed (Smith 1950)	
	Heavy metal tolerance:	relatively resistant to zinc, copper and lead (McLean and Jones 1975)
		Ulothricales are relatively resistant to zinc (Whitton 1970)
Blue-greens		
Lyngbya spp. Oscillatoria spp.	Heavy metal tolerance:	highly tolerant to relatively large zinc concentrations (Williams and Mount 1965)

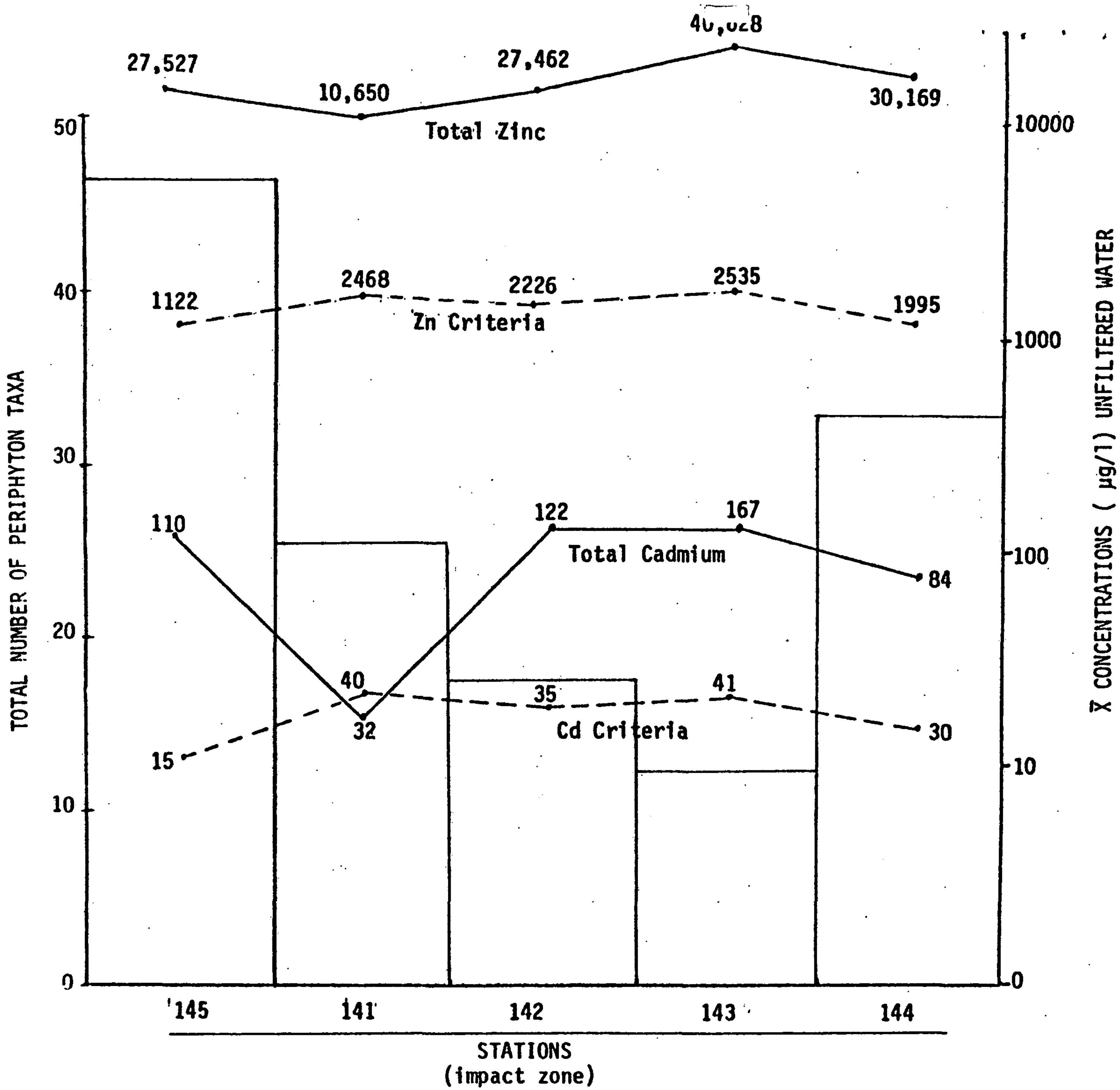


Figure 6. Comparison of periphyton species richness, mean concentrations of total zinc and cadmium, and calculated zinc and cadmium water quality criteria.

TABLE 13. LIST OF DIATOM TAXA (BACILLARIOPHYCEAE) REPORTED IN TAR CREEK, OKLAHOMA

Taxa	Station 145	141	142	143	144
Achnanthes lanceolata	x		x		
A. linearis			x		
A. minutissima	x	x	x	x	x
Amphipleura pellucida	x				
Anomoeoneis vitrea		x	x		
Caloneis bacillum					x
C. ventricosa var. *alpina*		x			
C. ventricosa var. *truncatula*					x
Cymbella minuta				x	
C. minuta var. *silesiaca*	x	x	x		
C. sinuata	x				
Cocconeis placentula	x				
Cyclotella atomus	x				
C. meneghiniana	x				x
Diatoma hiemale var. *mesoden*			x		
Eunotia spp.			x		
E. curvata	x				x
E. naegelii		x			
Fragilaria crotonensis		x			
Frustulia rhomboides var. *saxonica*	x				
Gomphonema parvulum	x		x		x
Hannaea arcus var. *amphioxys*			x		
Hantzschia spp.		x			
H. amphioxys			x		
Melosira islandica	x				
M. italica	x				
Meridion circulare var. *constrictum*	x	x			
Navicula spp.	x				x
N. arvensis	x				x
N. minima	x				
N. pelliculosa	x				
N. pupula var. *rectangularis*	x				
Neidium affine	x	x			

continued

TABLE 13. CONTINUED

Taxa	Station 145	141	142	143	144
Nitzschia spp.	x	x			x
N. acicularis					x
N. amphibia	x				
N. dissipata	x		x		
N. filiformis					x
N. ignorata	x				
N. palea	x				
N. pseudoamphioxys	x				
Pinnularia spp.	x				x
P. abaujensis var. *linearis*		x			x
P. major	x				
P. microstauron					x
P. stomatophora		x	x		
P. subcapitata	x				
Surirella angustata	x				
Synedra spp.				x	x
S. acus			x		
S. rumpens			x		
S. socia					x
S. ulna var. *amphirhynchus*					x

TABLE 14. LIST OF ALGAL TAXA (EXCLUSIVE OF DIATOMS) REPORTED IN TAR CREEK, OKLAHOMA

Taxa	Station 145	141	142	143	144
Chlorophyta					
Volvocales					
Carteria globosa	x				x
Chlamydomonas spp.	x			x	x
Scourfieldia cordiformis					x
Chlorococcales					
Ankyra spp.	x				
Chlorococcum sp.	x			x	x
Crucigenia tetrapedia	x				
Kirchneriella spp.		x			
Oocystis spp.	x				
Selenastrum sp.				x	
Scenedesmus abundans		x			x
S. acuminatus	x				x
S. bijuga	x				x
S. denticulatus					x
S. intermedius	x				
S. quadricauda		x			
Sphaerocystis schroeteri				x	
Tetraëdron spp.		x			
Ulothrichales					
Hormidium rivulare	x		x		
Ulothrix spp.			x		x
Oedogoniales					
Oedogonium spp.	x				
Zygnematales					
Cosmarium spp.	x				
Mougeotia spp.		x	x	x	x
Spirogyra spp.		x			
Pyrrhophyta					
Dinokontae					
Glenodinium spp.	x				
Euglenophyta					
Euglena acus				x	x
Trachelomonas spp.					x

continued

TABLE 14. CONTINUED

Taxa	Station 145	141	142	143	144
Cryptophyta					
Chilomonas spp.					x
Cryptomonas ovata					x
Cyanomonas americana	x			x	x
Rhodomonas minuta		x		x	x
Chrysophyta					
Ochromonadales					
Mallomonas spp.	x				x
Ochromonas spp.				x	x
Cyanophyta					
Chroococcales					
Chroococcus spp.		x			
Dactylococcopsis rhapidioides	x				
Oscillatoriales					
Lyngbya spp.		x			
Oscillatoria spp.	x	x			
Phormidium spp.		x		x	

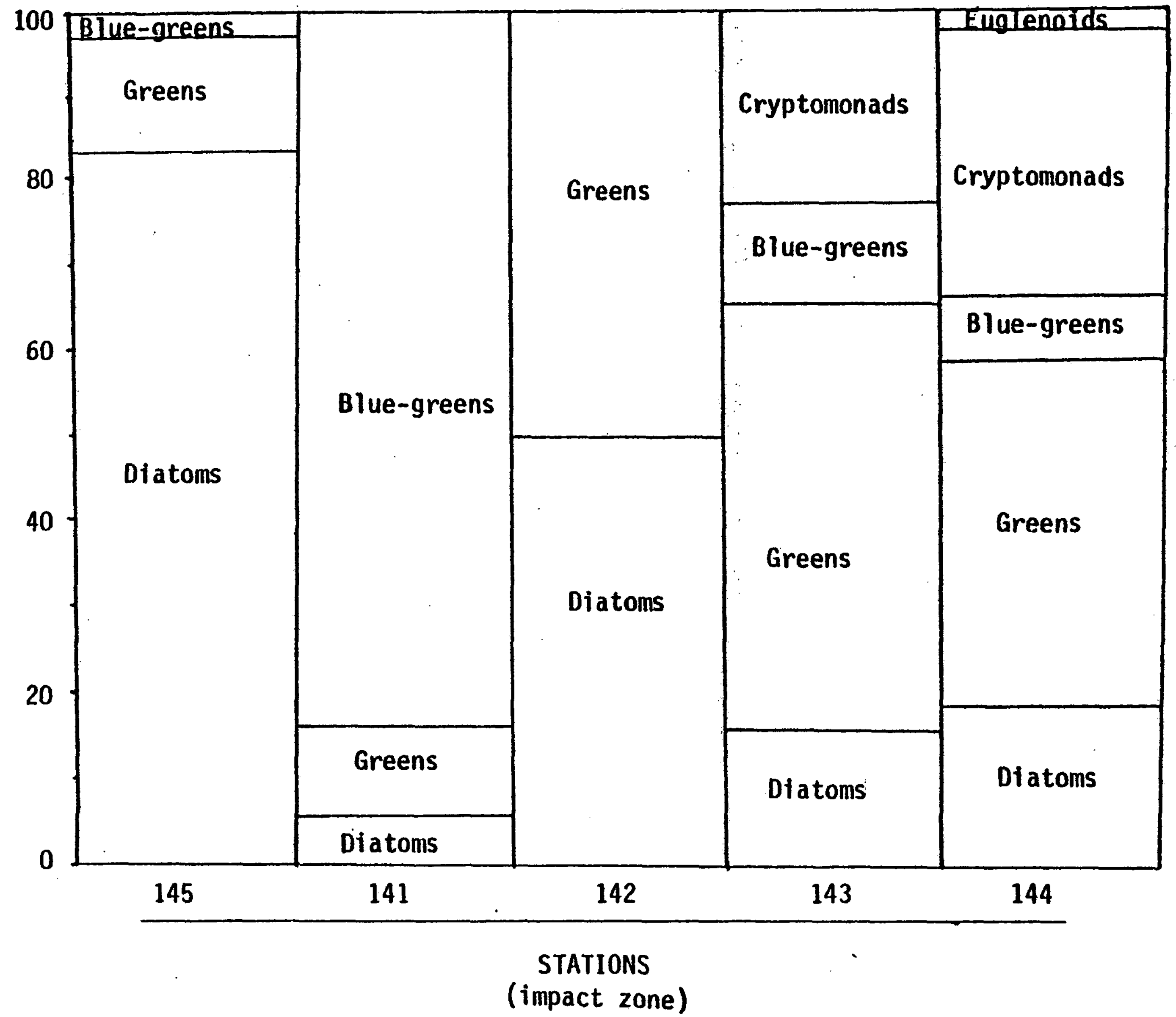


Figure 7. Algal group composition (percent) in Tar Creek, Oklahoma.

TABLE 15. TAXA CONTRIBUTING MORE THAN 5 PERCENT TO TOTAL PERIPHYTON ABUNDANCE IN TAR CREEK, OKLAHOMA. PERCENT COMPOSITION SHOWN IN PARENTHESIS

Station	Diatoms	Greens	Blue-greens	Cryptomonads
145	*Pinnularia subcapitata* (39) *Achnanthes minutissima* (19) *Nitzschia ignorata* (8)	*Hormidium rivulare* (5) *Chlorococcum* sp. (5)		
141		*Mougeotia* spp. (10)	*Lyngbya* spp. (32) *Chroococcus* spp. (24) *Phormidium* spp. (16) *Oscillatoria* spp. (11)	
142	*Anomoeoneis vitrea* (21) *Achnanthes minutissima* (19) *Cymbella minuta* var. *silesiaca* (7)	*Ulothrix* spp. (44) *Hormidium rivulare* (5)		
143		*Chlamydomonas* spp. (13) *Mougeotia* spp. (13) Monads < 10 μm (15)	*Phormidium* spp. (12)	*Cyanomonas americana* (22)
144	*Achnanthes minutissima* (5)	*Ulothrix* spp. (29)		*Cyanomonas americana* (29)

It is difficult to clearly differentiate substrate and metal effects on the periphyton community. Further testing, such as with artificial substrates, is necessary to help understand the effects of high metal concentrations on the periphyton community in Tar Creek.

Tissues

Grasses (Graminaceae) were collected from the banks at each station in Tar Creek. Zinc, nickel, silver, lead, and cadmium were measured in root, leaves and stems, and whole plant samples (Appendix D). Zinc, lead, and cadmium were found in excessively high concentrations; for example, root tissues and leaves and stem tissues contained up to 30,000 µg/g of zinc.

Zinc levels were higher than any values known in the literature. White (1976) reported that ambient zinc concentrations of 8865 µg/l resulted in 5971 µg/g in Equisetum roots, and 1358 µg/g in above ground parts. Potomogeton richardsonii exposed to 10 µg/l and 150 µg/l zinc resulted in zinc concentrations 198 and 1790 µg/g, respectively, in rhizomes and roots, and 171 and 2878 µg/g, respectively, in leaves and stems. Since ambient water concentrations in Tar Creek contained up to 40,000 µg/l zinc, it is reasonable to expect the extremely high tissue concentrations observed in this study. This can be compared to water samples collected from Prickly Pear Creek, Montana (Miller et al. 1982), which contained up to 3,296 µg/l ambient zinc concentrations and resulted in up to 1,000 µg/g zinc accumulation in root tissue, and 299 µg/g in leaves and stem tissues.

Cadmium levels in Tar Creek grasses ranged from nondetectable to 92 µg/g in root tissue, and from nondetectable to 48 µg/g in leaves and stem tissue. These cadmium values were generally only slightly higher than values obtained from Prickly Pear Creek even though ambient cadmium concentrations in Tar Creek were five times higher than those in Prickly Pear. Lead concentrations in Tar Creek grasses ranged up to 3,232 µg/g in root tissue, and up to 2,325 µg/g in leaves and stem tissue. Water and tissue concentrations of lead were very similar to those from Prickly Pear Creek.

Fish

Community Census

Mature fish were very sparse in Tar Creek, and were primarily collected during this study for purposes of analysis of metal concentrations in tissues. However, some qualitative observations were made during electroshocking. The fish species reported in Tar Creek were: green sunfish (Lepomis cyanellus), bluegill (Lepomis macrochirus), brown bullhead (Ictalurus nebulosus), golden shiner (Notemogonus crysoleucas), and mosquitofish (Gambusia affinis).

It is remarkable that any fish were found in Tar Creek. The EPA recommended acute criteria for zinc (adjusted for hardness) range from 1,122 µg/l to 2,535 µg/l, and from 15 µg/l to 41 µg/l for cadmium (U.S. EPA 1980). The actual ambient metal concentrations range from 10,650 to 40,628 µg/l for zinc, and from 23 to 167 µg/l for cadmium. Furthermore, the species mean acute value (mean LC50) for zinc is 293 µg/l (range = 108-796 µg/l) for bluegill (U.S. EPA 1980). Thus, fish collected in Tar Creek were resident in waters where the acute criteria were exceeded by more than an order of magnitude.

The significance of this phenomenon is increased by the fact that much of Tar Creek is characterized by a series of small pools isolated by manmade and natural barriers. These barriers essentially preclude upstream migration except during periodic times of flooding. Thus, fish surviving in the stream are often trapped for weeks or months at a time. These data present strong evidence that at least a few individuals were able to adjust to extremely high metal concentrations.

Tissues

As previously mentioned, few adult fish were collected from Tar Creek. However, as many individual fish tissues as possible were analyzed (Appendix D) to determine susceptibility of various tissues to metal accumulation.

Since metals enter Tar Creek primarily from nonpoint sources, control, impact, and recovery zones were not distinguishable. This situation was reflected in the tissue analysis results. Except for zinc, there was little difference observed between stations for any tissues. However, substantial accumulation of zinc, cadmium, and lead did occur in some tissues. Zinc concentrations in brain, gill, and liver tissues were above values for zinc-exposed fish reported in the literature (Mount 1964). Muscle tissues did not demonstrate any net accumulation of zinc. Cadmium and lead accumulated in gill and liver, but were not detectable in brain and muscle.

An interesting comparison can be made between these data and tissue data obtained from trout in Prickly Pear Creek, Montana (Miller et al. 1982). Although ambient total and dissolved concentrations of zinc, cadmium, and lead were 2-10 times higher in Tar Creek, metal concentrations in brain, gill, liver, and muscle tissues were generally below values obtained from Prickly Pear Creek fish. This apparent anomaly can probably be explained by the very high hardness levels in Tar Creek. The apparent ameliorating effect of hardness on the acute toxicity of metals is also reflected in reduced tissue accumulation of metals.

Total alkalinity is low and quite similar between Prickly Pear Creek (45-55 mg/l) and Tar Creek (55-75 mg/l). Thus, the well documented ameliorating effect of hardness on acute metal toxicity appears to be directly related to the calcium and magnesium hardness present in Tar Creek. Evidence for this phenomenon has been reported elsewhere (Miller and Mackay 1980; Lloyd 1965). Calcium induced reduction in surface membrane permeability has been suggested as a protection mechanism against metal poisoning (Skidmore 1964).

Bioassay

Bioassays were conducted at the Duluth laboratory on water from Stations 142 and 143 (Appendix E). In these analyses, no toxic response was observed for either station using the enzyme inhibition test. Results from the fish ventilation index test indicated stress to organisms from the sample waters, but this was not quantified.

For the algal toxicity tests, positive results were noted. Both samples 142 and 143 showed reduced toxicity after addition of EDTA, indicating that metals were the source of toxicity in the water samples. For the *Daphnia* tests, however, toxicity was not indicated. It was suggested that insufficient EDTA was added to complex the high zinc levels. Thus, the results were inconclusive.

It appears that water hardness in Tar Creek has a mitigating effect on the toxicity expected from such extremely high concentrations of zinc and cadmium, as predicted by EPA's criteria documents (U.S. EPA 1980). However, considering the extent to which the hardness-adjusted water quality criteria were exceeded (as much as 10-fold), a greater toxic effect was expected than was actually observed (e.g., a positive response in the enzyme tests, or perhaps a more quantifiable response in the activity index). This may be due to a greater toxicity-reducing capability of hardness at high concentrations than have been thus far tested, or to some other water chemical characteristic in Tar Creek or sampling error; hence, quantitative data are required to further evaluate this discrepancy.

IV. CONCLUSIONS

1. Ephemeral runoff from abandoned zinc and lead mines in the Picher Field delivers a significant amount of toxic metals to the Tar Creek watershed. Since metals enter Tar Creek primarily from nonpoint sources, control, impact, and recovery zones were not distinguishable.

2. Concentrations of cadmium, zinc, and silver exceed EPA recommended acute criteria at all stations in Tar Creek, with zinc concentrations generally exceeding criteria values by more than an order of magnitude.

3. Macroinvertebrate and periphyton data suggest that species distributions may relate as much to substrate characteristics and the absence of lotic flow as to elevated metal concentrations. The high hardness in Tar Creek appears to have a substantial mitigating influence on metal toxicity.

4. Fish (e.g., bluegill) were collected, although in limited numbers, where laboratory zinc LC_{50} values for the respective species were exceeded by more than an order of magnitude. Since Tar Creek fish are often trapped in isolated pools for weeks or months at a time, it appears that some animals (at least adult forms) are able to acclimate to extremely high ambient metal concentrations.

5. The lack of control, impact, and recovery zones was reflected in tissue analysis results, with few significant differences observed between stations for metal concentrations in tissues.

6. The apparent ameliorating effect of hardness on the acute toxicity of metals in Tar Creek is also reflected in reduced tissue metals accumulation. Data comparisons indicate that although ambient metal concentrations in Tar Creek were 2-10 times higher than those in Prickly Pear Creek, Montana, metal concentration in fish tissues from Tar Creek were generally below Prickly Pear fish.

V RECOMMENDATIONS

The results of this study raise several important questions concerning acclimation, metal speciation, and biological integrity or community health.

1. Additional sampling is recommended to examine the relationship between biological communities (macroinvertebrates, periphyton) and metal concentrations in Tar Creek. Use of alternative sampling techniques such as the use of artificial substrates would perhaps improve the comparability of data throughout the creek.

2. Considering the extent to which hardness-adjusted acute water quality criteria were exceeded in Tar Creek, a greater toxic effect was expected than was actually observed in the field or laboratory bioassay tests. This may be due to a greater toxicity-reducing capability of hardness at high concentrations than is presently known, to some other water chemistry characteristic in Tar Creek, or to sampling error. Additional quantitative data are required to further evaluate this discrepancy.

3. Additional study to examine the mechanism of acclimation to metals in resident fish species is needed. Since the Tar Creek fish population appears to be comprised of a relatively few hardy individuals, concentrations there may represent the upper limits of the acclimation process.

4. Human health considerations are the primary concern regarding elevated metals in Tar Creek. Tar Creek flows into the Neosho River and ultimately to Grand Lake, Oklahoma, which serves as a municipal water supply. Ambient concentrations in these latter water bodies should be monitored, at least for cadmium, zinc, lead, and silver. Considering the potential for bioaccumulation in consumable fish, tissue metal concentrations should also be regularly tested.

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APPENDIX A
WATER CHEMISTRY SUMMARY DATA

STORET RETRIEVAL DATE 82/02/01

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

14145441
37 01 00.0 094 51 00.0 5
MIAMI KANSAS CHEROKEE COUNTY TAR CRK
20021 KANSAS CHEROKEE
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
11EPATM 810131
0001 FEET DEPTH CLASS 00 CSN-RSP 0574952-0084100

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00094 CNDUCTVY FIELD MICROMHO	00299 DO PROBE MG/L	00400 PH SU	00410 T ALK CACO3 MG/L	00500 RESIDUE TOTAL MG/L	00530 RESIDUE TOT NFLT MG/L	00612 UN-IONZD NH3-N MG/L	00623 KJELDL N DISS MG/L	00630 NO2&NO3 N-TOTAL MG/L
80/10/31	11 00	0000	10.6	1310	13.4	6.25						
	11 10	0003	10.2	1320	13.4	6.29						
	11 20	0004	10.6	1320	13.4	6.34						
	11 30	0000					22	867	79	0.090	0.720	47.50
	11 30	0004	10.7	1320	13.6	6.37						
	11 31	0003					21	863	62	0.090	0.750	47.00
	11 32	0004					15	886	99	0.090	0.810	4.80
	11 33	0004					15	889	107	0.110	0.820	5.00
	11 34	0004					23	848	192	0.070	0.810	11.80
	11 35	0000					22	876	145	0.080	0.730	11.00
	11 40	0000	10.7	1310	13.6	6.40						

DATE FROM TO	TIME OF DAY	DEPTH FEET	00669 PHOS-TOT HYDRO MG/L P	00680 T ORG C C MG/L	50060 CHLORINE TOT RESD MG/L	50064 CHLORINE FREE AVL MG/L	82078 TURBIDIT Y FIELD NTU
80/10/31	11 00	0000			0.00	0.00	8.6
	11 10	0003					8.4
	11 20	0004					9.2
	11 30	0000	0.010	0.9			
	11 31	0003	0.010	11.6			
	11 32	0004	0.000				
	11 33	0004	0.000				
	11 34	0004	0.000				
	11 35	0000	0.000				

STORET RETRIEVAL DATE 82/02/01

14141441
37 00 00.0 094 51 00.0 5
MIAMI OKLAHOMA OTTAWA COUNTY TAR CREEK
40115 OKLAHOMA OTTAWA
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE 11EPATM 810124
0001 FEET DEPTH CLASS 00 CSN-RSP 0574617-0084090

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00094 CNDUCTVY FIELD MICROMHO	00299 DO PROBE MG/L	00400 PH SU	00410 T ALK CACO3 MG/L	00500 RESIDUE TOTAL MG/L	00530 RESIDUE TOT NFLT MG/L	00612 UN-IONZD NH3-N MG/L	00623 KJELDL N DISS MG/L	00630 NO2&NO3 N-TOTAL MG/L
80/10/29	15 00	0000	12.2	2410	9.5	7.68	90	1749	116	0.070	0.240	10.00
	15 01	0000					91	1743	150	0.100	0.240	9.20
	15 02	0000					91	1726	130	0.060	0.200	6.40
	15 03	0000					87	1727	5	0.070	0.250	6.50
	15 04	0001					87	1765	132	0.120	0.240	29.50
	15 05	0000					87	1691	122	0.150	0.330	26.50
	15 10	0000	12.2	2420	9.5	7.70						
	15 20	0000	11.7	2540	9.2	7.66						
	15 30	0001	10.7	2650	8.9	7.64						
	15 40	0000	11.7	2640	9.4	7.75						

DATE FROM TO	TIME OF DAY	DEPTH FEET	00669 PHOS-TOT HYDRO MG/L P	00680 T ORG C C MG/L	50060 CHLORINE TOT RESD MG/L	50064 CHLORINE FREE AVL MG/L	82078 TURBIDIT Y FIELD NTU
80/10/29	15 00	0000	0.000	2.5	0.00	0.00	5.3
	15 01	0000	0.000	3.2			
	15 02	0000	0.000				
	15 03	0000	0.000				
	15 04	0001	0.000				
	15 05	0000	0.000				
	15 10	0000			0.00	0.00	5.3
	15 20	0000					5.3

STORET RETRIEVAL DATE 82/02/01

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

14142441
36 59 30.0 094 51 00.0 5
MIAMI OKLAHOMA OTTAWA COUNTY TAR CREEK
40115 OKLAHOMA OTTAWA
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
11EPATH 810124
0002 FEET DEPTH CLASS 00 CSN-RSP 0574618-0084092

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00094 CNDUCTVY FIELD MICROMHO	00299 DO PROBE MG/L	00400 PH SU	00410 T ALK CACO3 MG/L	00500 RESIDUE TOTAL MG/L	00530 RESIDUE TOT NFLT MG/L	00612 UN-IONZD NH3-N MG/L	00623 KJELDL N DISS MG/L	00630 NO2&NO3 N-TOTAL MG/L
80/10/29	13 20	0000	12.3	2420	8.0	7.06						
	13 30	0000	12.0	2590	8.1	7.10	74	1670	134	0.050	0.310	1.30
	13 31	0000					74	1681	49	0.060	0.270	1.30
	13 32	0001					64	1591	45	0.060	0.310	1.30
	13 33	0001					63	1596	103	0.060	0.250	1.30
	13 34	0001					44		70	0.060	0.200	1.60
	13 35	0000					45		70	0.090	0.230	1.60
	13 40	0001	12.8	2950	9.8	7.17						
	13 50	0001	11.7	2870	8.7	7.17						
	14 00	0000	11.8	2440	8.6	7.24						

DATE FROM TO	TIME OF DAY	DEPTH FEET	00669 PHOS-TOT HYDRO MG/L P	00680 T ORG C C MG/L	50060 CHLORINE TOT RESD MG/L	50064 CHLORINE FREE AVL MG/L	82078 TURBIDIT Y FIELD NTU
80/10/29	13 20	0000			0.25	0.00	0.6
	13 30	0000	0.000	6.8	0.25	0.00	0.6
	13 31	0000	0.000	1.9			
	13 32	0001	0.000				
	13 33	0001	0.000				
	13 34	0001	0.000				
	13 35	0000	0.000				
	13 40	0001					0.5

STORET RETRIEVAL DATE 82/02/01

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

14143441
36 59 00.0 094 50 30.0 5
MIAMI OKLAHOMA OTTAWA COUNTY TAR CREEK
40115 OKLAHOMA OTTAWA
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
11EPATH 810124
0002 FEET DEPTH CLASS 00 CSN-RSP 0574619-0084094

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00094 CNDUCTVY FIELD MICROMHO	00299 DO PROBE MG/L	00400 PH SU	00410 T ALK CACO3 MG/L	00500 RESIDUE TOTAL MG/L	00530 RESIDUE TOT NFLT MG/L	00612 UN-IONZD NH3-N MG/L	00623 KJELDL N DISS MG/L	00630 NO2&NO3 N-TOTAL MG/L
80/10/30	09 00	0000	8.6	1930	8.9	6.56	56	1297	164	0.090	0.570	6.90
	09 01	0001					56	1269	159	0.120	0.540	7.10
	09 02	0000					54	1306	27	0.090	0.490	5.90
	09 03	0000					55	1246	3	0.110	0.640	6.00
	09 04	0000					24	1282	10	0.070	0.480	6.90
	09 05	0000					23	1299	3	0.090	0.380	7.00
	09 10	0001	8.5	1990	9.3	6.55						
	09 20	0000	8.3	2000	9.3	6.55						
	09 30	0000	8.3	1980	9.2	6.52						
	09 40	0000	8.6	1960	9.0	6.43						

DATE FROM TO	TIME OF DAY	DEPTH FEET	00669 PHOS-TOT HYDRO MG/L P	00680 T ORG C C MG/L	50060 CHLORINE TOT RESD MG/L	50064 CHLORINE FREE AVL MG/L	82078 TURBIDIT Y FIELD NTU
80/10/30	09 00	0000	0.010	3.7	0.20	0.04	1.8
	09 01	0001	0.010	1.3			
	09 02	0000	0.000				
	09 03	0000	0.000				
	09 04	0000	0.000				
	09 05	0000	0.000				
	09 10	0001			0.20	0.04	1.8
	09 20	0000					1.9

STORET RETRIEVAL DATE 82/02/01

14144441
36 58 00.0 094 50 30.0 5
MIAMI OKLAHOMA OTTAWA COUNTY TAR CREEK
40115 OKLAHOMA OTTAWA
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
11EPATM 810124
0001 FEET DEPTH CLASS 00 CSN-RSP 0574620-0084097

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

DATE FROM TO	TIME OF DAY	DEPTH FEET	00010 WATER TEMP CENT	00094 CNDUCTVY FIELD MICROMHO	00299 DO PROBE MG/L	00400 PH SU	00410 T ALK CACO3 MG/L	00500 RESIDUE TOTAL MG/L	00530 RESIDUE TOT NFLT MG/L	00612 UN-IONZD NH3-N MG/L	00623 KJELDL N DISS MG/L	00630 NO2&NO3 N-TOTAL MG/L
80/10/30	13 20	0000	10.1	2230	8.9	6.17						
	13 30	0000	10.1	2110	9.0	6.46						
	13 40	0000	9.7	2140	8.8	6.50	59	1526	96	0.060	0.450	5.90
	13 41	0000					59	1525	34	0.080	0.390	5.90
	13 42	0000					62	1502	35	0.180	0.430	5.90
	13 43	0000					61	1521	44	0.220	0.440	4.70
	13 44	0000					48	1564	53	0.080	0.570	3.90
	13 45	0000					49	1524	42	0.090	0.580	4.00
	13 50	0000	9.7	2150	9.0	6.54						
	14 00	0000	9.4	2160	8.6	6.53						

DATE FROM TO	TIME OF DAY	DEPTH FEET	00669 PHOS-TOT HYDRO MG/L P	00680 T ORG C C MG/L	50060 CHLORINE TOT RESD MG/L	50064 CHLORINE FREE AVL MG/L	82078 TURBIDIT Y FIELD NTU
80/10/30	13 20	0000			0.40	0.02	2.2
	13 30	0000			0.40	0.02	2.5
	13 40	0000	0.010	2.3			3.2
	13 41	0000	0.000	2.9			
	13 42	0000	0.000				
	13 43	0000	0.000				
	13 44	0000	0.000				
	13 45	0000	0.000				

STORET RETRIEVAL DATE 82/02/01

14145441
37 01 00.0 094 51 00.0 5
MIAMI KANSAS CHEROKEE COUNTY TAR CRK
20021 KANSAS CHEROKEE
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE 11EPATM 810131
0001 FEET DEPTH CLASS 00 CSN-RSP 0574952-0084100

DATE FROM TO	TIME OF DAY	DEPTH FEET	01025 CADMIUM CD,DISS UG/L	01027 CADMIUM CD,TOT UG/L	01049 LEAD PB,DISS UG/L	01051 LEAD PB,TOT UG/L	01090 ZINC ZN,DISS UG/L	01092 ZINC ZN,TOT UG/L	01065 NICKEL NI,DISS UG/L	01067 NICKEL NI,TOTAL UG/L	01075 SILVER AG,DISS UG/L	01077 SILVER AG,TOT UG/L
80/10/31	11 30	0000	105	120	362	552	25300	25900	123	168	116.0	193.0
	11 32	0000	111	128	445	645	25800	26600	128	176	137.0	210.0
	11 34	0000	109	106	443	543	25500	22800	126	159	117.0	123.0
	11 36	0000	110	108	430	460	25800	24200	113	148	115.0	121.0
	11 38	0000	109	107	441	516	25000	24700	137	133	110.0	136.0
	11 40	0000	108	110	409	471	25200	25200	141	126	111.0	125.0
	11 31											
CP(T)-03	AVE	0000		115		481		26300		135		141.0
80/10/31	13 31											
	12 31											
CP(T)-03	AVE	0000		116		496		26700		139		134.0
80/10/31	14 31											
	13 31											
CP(T)-03	AVE	0000		115		526		26100		146		152.0
80/10/31	15 31											
	14 31											
CP(T)-03	AVE	0000		114		475		26700		119		141.0
80/10/31	16 31											
	15 31											
CP(T)-03	AVE	0000		109		488		26200		151		160.0
80/10/31	17 31											
	16 31											
CP(T)-03	AVE	0000		111		456		27000		131		138.0
80/10/31	18 31											
	17 31											
CP(T)-03	AVE	0000		111		524		26400		154		168.0
80/10/31	19 31											
	18 31											
CP(T)-03	AVE	0000		111		462		27000		140		152.0
80/10/31	20 31											
	19 31											
CP(T)-03	AVE	0000		106		441		26700		128		136.0
80/10/31	21 31											
	20 31											
CP(T)-03	AVE	0000		105		411		27000		126		142.0
80/10/31	22 31											

STORET RETRIEVAL DATE 82/02/01

14145441
37 01 00.0 094 51 00.0 5
MIAMI KANSAS CHEROKEE COUNTY TAR CRK
20021 KANSAS CHEROKEE
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
11EPATM 810131
0001 FEET DEPTH CLASS 00 CSN-RSP 0574952-0084100

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

DATE FROM TO	TIME OF DAY	DEPTH FEET	01000 ARSENIC AS,DISS UG/L	01002 ARSENIC AS,TOT UG/L
80/10/31	11 30	0000	264	368
	11 32	0000	210	335
	11 34	0000	205	484
	11 36	0000	149	308
	11 38	0000	238	271
	11 40	0000	45	202
	11 31			
CP(T)-03	AVE	0000		250
80/10/31	13 31			
	12 31			
CP(T)-03	AVE	0000		207
80/10/31	14 31			
	13 31			
CP(T)-03	AVE	0000		254
80/10/31	15 31			
	14 31			
CP(T)-03	AVE	0000		173
80/10/31	16 31			
	15 31			
CP(T)-03	AVE	0000		315
80/10/31	17 31			
	16 31			
CP(T)-03	AVE	0000		174
80/10/31	18 31			
	17 31			
CP(T)-03	AVE	0000		245
80/10/31	19 31			
	18 31			
CP(T)-03	AVE	0000		119
80/10/31	20 31			
	19 31			
CP(T)-03	AVE	0000		188
80/10/31	21 31			
	20 31			
CP(T)-03	AVE	0000		68
80/10/31	22 31			

STORET RETRIEVAL DATE 82/02/01

14145441
37 01 00.0 094 51 00.0 5
MIAMI KANSAS CHEROKEE COUNTY TAR CRK
20021 KANSAS CHEROKEE
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE
11EPATM 810131
0001 FEET DEPTH CLASS 00 CSN-RSP 0574952-0084100

DATE FROM TO	TIME OF DAY	DEPTH FEET	01025 CADMIUM CD,DISS UG/L	01027 CADMIUM CD,TOT UG/L	01049 LEAD PB,DISS UG/L	01051 LEAD PB,TOT UG/L	01090 ZINC ZN,DISS UG/L	01092 ZINC ZN,TOT UG/L	01065 NICKEL NI,DISS UG/L	01067 NICKEL NI,TOTAL UG/L	01075 SILVER AG,DISS UG/L	01077 SILVER AG,TOT UG/L
80/10/31	21 31											
CP(T)-03	AVE	0000		104		432		26500		121		135.0
80/10/31	23 31											
	22 31											
CP(T)-03	AVE	0000		104		443		26700		94		134.0
80/11/01	00 31											
80/10/31	23 31											
CP(T)-03	AVE	0000		104		439		26300		134		124.0
80/11/01	01 31											
	00 31											
CP(T)-03	AVE	0000		105		422		26700		105		126.0
80/11/01	02 31											
	08 31											
CP(T)-03	AVE	0000		109		530		26800		155		167.0
80/11/01	10 31											
	09 31											
CP(T)-03	AVE	0000		106		496		27300		139		162.0
80/11/01	11 31											
	10 31											
CP(T)-03	AVE	0000		104		234		34600		39		12.0
80/11/01	12 31											
	11 31											
CP(T)-03	AVE	0000		106		119		35100		42		27.0
80/11/01	13 31											
	12 31											
CP(T)-03	AVE	0000		109		181		35200		76		38.0
80/11/01	14 31											
	13 31											
CP(T)-03	AVE	0000		111		160		35000		29		44.0
80/11/01	15 31											

STORET RETRIEVAL DATE 82/02/01

14145441
37 01 00.0 094 51 00.0 5
MIAMI KANSAS CHEROKEE COUNTY TAR CRK
20021 KANSAS CHEROKEE
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
11EPATM 810131
0001 FEET DEPTH CLASS 00 CSN-RSP 0574952-0084100

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

DATE FROM TO	TIME OF DAY	DEPTH FEET	01000 ARSENIC AS,DISS UG/L	01002 ARSENIC AS,TOT UG/L
80/10/31	21 31			
CP(T)-03	AVE	0000		177
80/10/31	23 31			
	22 31			
CP(T)-03	AVE	0000		65
80/11/01	00 31			
	00 31			
CP(T)-03	AVE	0000		72
80/11/01	02 31			
	08 31			
CP(T)-03	AVE	0000		307
80/11/01	10 31			
	09 31			
CP(T)-03	AVE	0000		169
80/11/01	11 31			
	10 31			
CP(T)-03	AVE	0000		56
80/11/01	12 31			
	11 31			
CP(T)-03	AVE	0000		9
80/11/01	13 31			
	12 31			
CP(T)-03	AVE	0000		182
80/11/01	14 31			

STORET RETRIEVAL DATE 82/02/01

14141441
37 00 00.0 094 51 00.0 5
MIAMI OKLAHOMA OTTAWA COUNTY TAR CREEK
40115 OKLAHOMA OTTAWA
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE
11EPATM 810124
0001 FEET DEPTH CLASS 00 CSN-RSP 0574617-0084090

DATE FROM TO	TIME OF DAY	DEPTH FEET	01025 CADMIUM CD,DISS UG/L	01027 CADMIUM CD,TOT UG/L	01049 LEAD PB,DISS UG/L	01051 LEAD PB,TOT UG/L	01090 ZINC ZN,DISS UG/L	01092 ZINC ZN,TOT UG/L	01065 NICKEL NI,DISS UG/L	01067 NICKEL NI,TOTAL UG/L	01075 SILVER AG,DISS UG/L	01077 SILVER AG,TOT UG/L
80/10/29	15 00	0000	28	31	247	309	10200	10500	70	76	35.0	27.0
	15 02	0000	27	30	209	271	10300	10600	59	75	32.0	40.0
	15 04	0000	24	30	183	258	10200	10600	22	43	35.0	27.0
	15 06	0000	25	34	156	292	10200	10700	37	83	29.0	53.0
	15 08	0000	29	34	213	254	10300	10700	64	45	30.0	29.0
	15 10	0000	29	36	228	315	10400	10800	69	57	23.0	46.0

DATE FROM TO	TIME OF DAY	DEPTH FEET	01000 ARSENIC AS,DISS UG/L	01002 ARSENIC AS,TOT UG/L
80/10/29	15 00	0000	36	143
	15 04	0000		96
	15 08	0000	26	87

STORET RETRIEVAL DATE 82/02/01

14142441
36 59 30.0 094 51 00.0 5
MIAMI OKLAHOMA OTTAWA COUNTY TAR CREEK
40115 OKLAHOMA OTTAWA
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE 11EPATM 810124
0002 FEET DEPTH CLASS 00 CSN-RSP 0574618-0084092

DATE FROM TO	TIME OF DAY	DEPTH FEET	01025 CADMIUM CD,DISS UG/L	01027 CADMIUM CD,TOT UG/L	01049 LEAD PB,DISS UG/L	01051 LEAD PB,TOT UG/L	01090 ZINC ZN,DISS UG/L	01092 ZINC ZN,TOT UG/L	01065 NICKEL NI,DISS UG/L	01067 NICKEL NI,TOTAL UG/L	01075 SILVER AG,DISS UG/L	01077 SILVER AG,TOT UG/L
80/10/29	13 30	0000	113	122	217	273	27500	27500	85	92	42.0	35.0
	13 32	0000	117	122	236	271	27900	27700	80	115	23.0	48.0
	13 34	0000	115	121	136	277	26800	26700	64	87	16.0	47.0
	13 36	0000	116	122	181	266	26900	27100	64	112	17.0	39.0
	13 38	0000	121	121	160	264	28400	26900	61	89	11.0	54.0
	13 40	0000	124	121	256	258	28500	27100	81	98	31.0	36.0
	13 42	0000		125		290		28200		107		53.0
	13 44	0000		123		232		28500		88		35.0

DATE FROM TO	TIME OF DAY	DEPTH FEET	01000 ARSENIC AS,DISS UG/L	01002 ARSENIC AS,TOT UG/L
80/10/29	13 30	0000	20	146
	13 32	0000		36
	13 34	0000		145
	13 38	0000	12	129
	13 42	0000		127

STORET RETRIEVAL DATE 82/02/01

14143441
36 59 00.0 094 50 30.0 5
MIAMI OKLAHOMA OTTAWA COUNTY TAR CREEK
40115 OKLAHOMA OTTAWA
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE 11EPATM 810124
0002 FEET DEPTH CLASS 00 CSN-RSP 0574619-0084094

DATE FROM TO	TIME OF DAY	DEPTH FEET	01025 CADMIUM CD,DISS UG/L	01027 CADMIUM CD,TOT UG/L	01049 LEAD PB,DISS UG/L	01051 LEAD PB,TOT UG/L	01090 ZINC ZN,DISS UG/L	01092 ZINC ZN,TOT UG/L	01065 NICKEL NI,DISS UG/L	01067 NICKEL NI,TOTAL UG/L	01075 SILVER AG,DISS UG/L	01077 SILVER AG,TOT UG/L
80/10/30	09 00	0000	281	280	232	254	37800	37700	90	98	35.0	36.0
	09 02	0000	278	277	273	260	37900	38000	102	111	62.0	36.0
	09 04	0000	273	272	243	234	38300	38300	73	127	44.0	40.0
	09 06	0000	275	277	245	305	38400	38800	99	121	52.0	53.0
	09 08	0000	279	282	209	334	38100	37700	87	107	59.0	52.0
	09 10	0000	278	282	239	328	37800	37700	87	118	52.0	58.0
	09 01											
CP(T)-03	AVE	0000		102		317		40000		121		87.0
80/10/30	11 01											
	10 01											
CP(T)-03	AVE	0000		103		337		40500		122		82.0
80/10/30	12 01											
	11 01											
CP(T)-03	AVE	0000		93		215		42500		87		28.0
80/10/30	13 01											
	12 01											
CP(T)-03	AVE	0000		99		315		43700		97		66.0
80/10/30	14 01											
	15 01											
CP(T)-03	AVE	0000		111		264		40800		85		55.0
80/10/30	17 01											
	16 01											
CP(T)-03	AVE	0000		115		394		41300		105		77.0
80/10/30	18 01											
	17 01											
CP(T)-03	AVE	0000		119		394		40200		109		83.0
80/10/30	19 01											
	18 01											
CP(T)-03	AVE	0000		124		418		40600		119		86.0
80/10/30	20 01											
	19 01											
CP(T)-03	AVE	0000		117		386		42400		147		104.0
80/10/30	21 01											
	20 01											
CP(T)-03	AVE	0000		119		377		43100		122		104.0
80/10/30	22 01											
80/10/30	21 01											
CP(T)-03	AVE	0000		119		392		43400		140		114.0
80/10/30	23 01											
	22 01											
CP(T)-03	AVE	0000		123		467		44600		145		149.0
80/10/31	00 01											

STORET RETRIEVAL DATE 82/02/01

14143441
36 59 00.0 094 50 30.0 5
MIAMI OKLAHOMA OTTAWA COUNTY TAR CREEK
40115 OKLAHOMA OTTAWA
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
11EPATM 810124
0002 FEET DEPTH CLASS 00 CSN-RSP 0574619-0084094

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

DATE FROM TO	TIME OF DAY	DEPTH FEET	01000 ARSENIC AS,DISS UG/L	01002 ARSENIC AS,TOT UG/L
80/10/30	09 00	0000	188	146
	09 02	0000	44	23
	09 04	0000	128	77
	09 06	0000	44	27
	09 08	0000	27	132
	09 10	0000	76	60
	09 01			
CP(T)-03	AVE	0000		57
80/10/30	11 01			
	10 01			
CP(T)-03	AVE	0000		8
80/10/30	12 01			
	15 01			
CP(T)-03	AVE	0000		32
80/10/30	17 01			
	16 01			
CP(T)-03	AVE	0000		84
80/10/30	18 01			
	17 01			
CP(T)-03	AVE	0000		121
80/10/30	19 01			
	18 01			
CP(T)-03	AVE	0000		101
80/10/30	20 01			
	19 01			
CP(T)-03	AVE	0000		102
80/10/30	21 01			
	20 01			
CP(T)-03	AVE	0000		66
80/10/30	22 01			
	21 01			
CP(T)-03	AVE	0000		122
80/10/30	23 01			
	22 01			
CP(T)-03	AVE	0000		61
80/10/31	00 01			

STORET RETRIEVAL DATE 82/02/01

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

14144441
36 58 00.0 094 50 30.0 5
MIAMI OKLAHOMA OTTAWA COUNTY TAR CREEK
40115 OKLAHOMA OTTAWA
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
11EPATM 810124
0001 FEET DEPTH CLASS 00 CSN-RSP 0574620-0084097

DATE FROM TO	TIME OF DAY	DEPTH FEET	01025 CADMIUM CD,DISS UG/L	01027 CADMIUM CD,TOT UG/L	01049 LEAD PB,DISS UG/L	01051 LEAD PB,TOT UG/L	01090 ZINC ZN,DISS UG/L	01092 ZINC ZN,TOT UG/L	01065 NICKEL NI,DISS UG/L	01067 NICKEL NI,TOTAL UG/L	01075 SILVER AG,DISS UG/L	01077 SILVER AG,TOT UG/L
80/10/30	13 40	0000	82	89	616	313	26700	41500	207	121	173.0	102.0
	13 42	0000	85	89	660	334	26700	41500	206	116	178.0	117.0
	13 44	0000	84	88	648	322	26800	41100	241	119	172.0	118.0
	13 46	0000	87	86	631	311	27500	42000	223	120	200.0	96.0
	13 48	0000	87	88	658	279	27700	41600	203	90	200.0	92.0
	13 50	0000	86	91	654	296	28300	42800	176	72	211.0	126.0
	13 41											
CP(T)-03	AVE	0000		79		635		24900		182		195.0
80/10/30	15 41											
	14 41											
CP(T)-03	AVE	0000		77		637		25000		181		188.0
80/10/30	16 41											
	15 41											
CP(T)-03	AVE	0000		74		571		25700		138		173.0
80/10/30	17 41											
	16 41											
CP(T)-03	AVE	0000		76		620		26100		192		180.0
80/10/30	18 41											
	17 41											
CP(T)-03	AVE	0000		83		722		26100		206		201.0
80/10/30	19 41											
	18 41											
CP(T)-03	AVE	0000		84		763		26600		197		180.0
80/10/30	20 41											
	22 41											
CP(T)-03	AVE	0000		87		694		26900		245		209.0
80/10/31	00 41											
80/10/30	23 41											
CP(T)-03	AVE	0000		85		707		26600		200		191.0
80/10/31	01 41											
	00 41											
CP(T)-03	AVE	0000		85		743		26600		200		207.0
80/10/31	02 41											
	01 41											
CP(T)-03	AVE	0000		85		729		27100		213		210.0
80/10/31	03 41											

STORET RETRIEVAL DATE 82/02/01

14144441
36 58 00.0 094 50 30.0 5
MIAMI OKLAHOMA OTTAWA COUNTY TAR CREEK
40115 OKLAHOMA OTTAWA
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
11EPATM 810124
0001 FEET DEPTH CLASS 00 CSN-RSP 0574620-0084097

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

DATE FROM TO	TIME OF DAY	DEPTH FEET	01000 ARSENIC AS,DISS UG/L	01002 ARSENIC AS,TOT UG/L
80/10/30	13 40	0000	422	147
	13 42	0000	390	88
	13 44	0000	390	163
	13 46	0000	335	54
	13 48	0000	380	75
	13 50	0000	303	
	13 41			
CP(T)-03	AVE	0000		386
80/10/30	15 41			
	14 41			
CP(T)-03	AVE	0000		247
80/10/30	16 41			
	15 41			
CP(T)-03	AVE	0000		289
80/10/30	17 41			
	16 41			
CP(T)-03	AVE	0000		256
80/10/30	18 41			
	17 41			
CP(T)-03	AVE	0000		345
80/10/30	19 41			
	18 41			
CP(T)-03	AVE	0000		261
80/10/30	20 41			
	22 41			
CP(T)-03	AVE	0000		456
80/10/31	00 41			
80/10/30	23 41			
CP(T)-03	AVE	0000		361
80/10/31	01 41			
	00 41			
CP(T)-03	AVE	0000		427
80/10/31	02 41			
	01 41			
CP(T)-03	AVE	0000		277
80/10/31	03 41			

STORET RETRIEVAL DATE 82/02/01

14144441
36 58 00.0 094 50 30.0 5
MIAMI OKLAHOMA   OTTAWA COUNTY TAR CREEK
40115   OKLAHOMA   OTTAWA
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE   11EPATM   810124
0001 FEET DEPTH CLASS 00 CSN-RSP 0574620-0084097

DATE FROM TO	TIME OF DAY	DEPTH FEET	01025 CADMIUM CD,DISS UG/L	01027 CADMIUM CD,TOT UG/L	01049 LEAD PB,DISS UG/L	01051 LEAD PB,TOT UG/L	01090 ZINC ZN,DISS UG/L	01092 ZINC ZN,TOT UG/L	01065 NICKEL NI,DISS UG/L	01067 NICKEL NI,TOTAL UG/L	01075 SILVER AG,DISS UG/L	01077 SILVER AG,TOT UG/L
80/10/31	02 41											
CP(T)-03	AVE	0000		83		665		27000		212		208.0
80/10/31	04 41											
	03 41											
CP(T)-03	AVE	0000		87		707		27500		181		220.0
80/10/31	05 41											
	04 41											
CP(T)-03	AVE	0000		86		758		27600		198		218.0
80/10/31	06 41											
	05 41											
CP(T)-03	AVE	0000		81		660		28000		166		197.0
80/10/31	07 41											
	06 41											
CP(T)-03	AVE	0000		84		648		27900		177		230.0
80/10/31	08 41											
	07 41											
CP(T)-03	AVE	0000		86		669		28000		200		220.0
80/10/31	09 41											
	08 41											
CP(T)-03	AVE	0000		78		601		26200		184		192.0
80/10/31	10 41											
	09 41											
CP(T)-03	AVE	0000		79		658		26500		181		205.0
80/10/31	11 41											
	10 41											
CP(T)-03	AVE	0000		81		637		26500		186		198.0
80/10/31	12 41											
	11 41											
CP(T)-03	AVE	0000		85		699		27100		171		212.0
80/10/31	13 41											

STORET RETRIEVAL DATE 82/02/01

14144441
36 58 00.0 094 50 30.0 5
MIAMI OKLAHOMA OTTAWA COUNTY TAR CREEK
40115 OKLAHOMA OTTAWA
SOUTH CENTRAL LOW MISS R 100400
GRAND NEOSHO RIVER
11EPATM 810124
0001 FEET DEPTH CLASS 00 CSN-RSP 0574620-0084097

/TYPA/AMBNT/FISH/STREAM/NONPNT/TISSUE

DATE FROM TO	TIME OF DAY	DEPTH FEET	01000 ARSENIC AS,DISS UG/L	01002 ARSENIC AS,TOT UG/L
80/10/31	02 41			
CP(T)-03	AVE	0000		397
80/10/31	04 41			
	03 41			
CP(T)-03	AVE	0000		386
80/10/31	05 41			
	04 41			
CP(T)-03	AVE	0000		453
80/10/31	06 41			
	05 41			
CP(T)-03	AVE	0000		224
80/10/31	07 41			
	06 41			
CP(T)-03	AVE	0000		395
80/10/31	08 41			
	07 41			
CP(T)-03	AVE	0000		289
80/10/31	09 41			
	08 41			
CP(T)-03	AVE	0000		314
80/10/31	10 41			
	09 41			
CP(T)-03	AVE	0000		195
80/10/31	11 41			
	10 41			
CP(T)-03	AVE	0000		324
80/10/31	12 41			
	11 41			
CP(T)-03	AVE	0000		257
80/10/31	13 41			

APPENDIX B
MACROINVERTEBRATE CENSUS DATA

PROJECT: TOXIC METALS PROJECT (TM) AREA: TAR CREEK, OAKLAHOMA (14) DATE: OCTOBER 31, 1980
STATION: 1 MILE N. OF OAKLAHOMA/KANSAS ST. LINE, 1 MILE WEST OF HWY 6 SUBSTATION: 281
SAMPLER TYPE: 30 SECOND KICK - 30 MESH TRIANGULAR NET (6)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: BRYANT NESS (54)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
DIPTERA					
TABANIDAE					
CHRYSOPS SP. (19100)	1 - 3	0.	0.	1.	1.
COLEOPTERA					
DYTISCIDAE					
HYDROPORUS SP. - ADULT (20430)	1 - 3	1.	1.	0.	2.
TOTAL FOR 2 SPECIES BY REPLICATE:	1 - 3	1.	1.	1.	
TOTAL FOR 3 REPLICATES, 2 SPECIES:		3.			

PROJECT: TOXIC METALS PROJECT (TM) AREA: TAR CREEK, OAKLAHOMA (14) DATE: OCTOBER 29, 1980
STATION: STATELINE ROAD, 1 MILE WEST OF HWY 69 (141) SUBSTATION: 251
SAMPLER TYPE: 30 SECOND KICK - 30 MESH TRIANGULAR NET (6)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: CHARLIE KEENAN (53)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
ODONATA-ANISOPTERA					
LIBELLULIDAE					
ERYTHEMIS SP. (4850)	1 - 3	3.	0.	3.	6.
CELITHEMIS SP. (4870)	1 - 3	0.	1.	0.	1.
ORTHEMIS FERRUGINEA (4900)	1 - 3	1.	0.	1.	2.
ODONATA-ZYGOPTERA					
COENAGRIONIDAE					
ARGIA SP. (5310)	1 - 3	1.	0.	0.	1.
ENALLAGMA/ISCHNURA COMPLEX (5410)	1 - 3	9.	1.	18.	28.
TRICHOPTERA					
HYDROPSYCHIDAE					
HYDROPSYCHE SPP. (6860)	1 - 3	0.	1.	0.	1.
DIPTERA					
CHIRONOMIDAE, S-FAM ORTHOCLADIINAE					
-ALL- (14110)	1 - 3	0.	1.	3.	4.
TOTAL FOR 7 SPECIES BY REPLICATE:	1 - 3	14.	4.	25.	
TOTAL FOR 3 REPLICATES, 7 SPECIES:		43.			

PROJECT: TOXIC METALS PROJECT (TM) AREA: TAR CREEK, OAKLAHOMA (14) DATE: NOVEMBER 1, 1980
STATION: 0.25 MILES S STATELINE ROAD, 1 MILE WEST OF HWY 69 (142) SUBSTATION: 281
SAMPLER TYPE: 30 SECOND KICK - 30 MESH TRIANGULAR NET (6)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: CHARLIE KEENAN (53)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
DIPTERA					
CULICIDAE					
AEDES SP. (17820)	1 - 3	1.	16.	2.	19.
LEPIDOPTERA					
PYRALIDAE					
-ALL- (19600)	1 - 3	0.	1.	0.	1.
TOTAL FOR 2 SPECIES BY REPLICATE:	1 - 3	1.	17.	2.	
TOTAL FOR 3 REPLICATES, 2 SPECIES:		20.			

PROJECT: TOXIC METALS PROJECT (TM) AREA: TAR CREEK, OAKLAHOMA (14) DATE: OCTOBER 30, 1980
STATION: PICHER HIGH SCHOOL ROAD, 0.66 MILES WEST OF HWY 69 (143) SUBSTATION: 25:
SAMPLER TYPE: 30 SECOND KICK - 30 MESH TRIANGULAR NET (6)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: CHARLIE KEENAN (83)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
ODONATA-ANISOPTERA					
LIBELLULIDAE					
ERYTHEMIS SP. (4050)	1 - 3	0.	1.	0.	1.
CELITHEMIS SP. (4070)	1 - 3	0.	0.	1.	1.
ODONATA-ZYGOPTERA					
COENAGRIONIDAE					
ARGIA SP. (5310)	1 - 3	16.	2.	3.	21.
ENALLAGMA/ISCHNURA COMPLEX (5410)	1 - 3	0.	2.	0.	2.
MEGALOPTERA					
SIALIDAE					
SIALIS SP. (5790)	1 - 3	0.	1.	0.	1.
TRICHOPTERA					
HYDROPTILIDAE					
OXYETHIRA SP. (7870)	1 - 3	1.	0.	1.	2.
DIPTERA					
CHIRONOMIDAE					
-ALL- (10510)	1 - 3	1.	9.	7.	17.
CHIRONOMIDAE, S-FAM ORTHOCLADIINAE					
-ALL- (14110)	1 - 3	28.	45.	43.	116.
CULICIDAE					
AEDES SP. (17820)	1 - 3	1.	0.	0.	1.
COLEOPTERA					
DYTISCIDAE					
RHANTUS-COLYMBETES SP. (20415)	1 - 3	0.	1.	0.	1.
HYDROPHILIDAE					
BEROSUS SP. (20800)	1 - 3	0.	1.	0.	1.

TOTAL FOR 11 SPECIES BY REPLICATE:	1 - 3	47.	62.	55.
TOTAL FOR 3 REPLICATES, 11 SPECIES:		164.		

PROJECT: TOXIC METALS PROJECT (TM)   AREA: TAR CREEK, OAKLAHOMA (14)   DATE: OCTOBER 30, 1980
STATION: CARDIN ROAD AT CARDIN (144)   SUBSTATION: 351
SAMPLER TYPE: 30 SECOND KICK - 30 MESH TRIANGULAR NET (6)
NUMBER OF REPLICATES: 3   FIELD BIOLOGIST: BRYANT HESS (54)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
ODONATA-ANISOPTERA					
LIBELLULIDAE					
ERYTHEMIS SP. (4850)	1 - 3	0.	1.	0.	1.
HEMIPTERA					
CORIXIDAE					
-ALL- (6010)	1 - 3	2.	10.	0.	12.
DIPTERA					
CHIRONOMIDAE					
-ALL- (10510)	1 - 3	0.	1.	0.	1.
CHIRONOMIDAE, S-FAMILY-CHIRONOMINAE					
-ALL- (12110)	1 - 3	7.	4.	179.	190.
CHIRONOMIDAE, S-FAM ORTHOCLADIINAE					
-ALL- (14110)	1 - 3	22.	15.	6.	43.
CULICIDAE					
AEDES SP. (17820)	1 - 3	1.	5.	0.	6.
CERATOPOGONIDAE					
PALPOMYIA GROUP (18040)	1 - 3	27.	23.	8.	58.
TABANIDAE					
CHRYSOPS SP. (19100)	1 - 3	0.	0.	1.	1.
COLEOPTERA					
DYTISCIDAE					
RHANTUS-COLYMBETES SP. (20415)	1 - 3	0.	1.	0.	1.
OLIGOCHAETA					
-ALL- (59010)	1 - 3	235.	53.	277.	565.

TOTAL FOR 10 SPECIES BY REPLICATE: 1 - 3   294.   113.   471.

TOTAL FOR 3 REPLICATES, 10 SPECIES: 878.

PROJECT: TOXIC METALS PROJECT (TM) AREA: TAR CREEK, OAKLAHOMA (14) DATE: OCTOBER 31, 1980
STATION: 1 MILE N. OF OAKLAHOMA/KANSAS ST. LINE, 1 MILE WEST OF HWY 6 SUBSTATION: 511
SAMPLER TYPE: QUALITATIVE EPIPHYTON SCRAPE (29)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (60)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
CHLOROPHYTA					
COLONIES (30)	1 - 3	24.	0.	6.	30.
VOLVOCALES					
CARTERIA GLOBOSA (870)	1 - 3	19.	2.	15.	36.
CHLAMYDOMONAS SPP. (1870)	1 - 3	0.	0.	2.	2.
CHLOROCOCCALES					
ANKYRA SPP. (10020)	1 - 3	1.	0.	1.	2.
OOCYSTIS SPP. (15210)	1 - 3	0.	6.	0.	6.
CRUCIGENIA TETRAPEDIA (18420)	1 - 3	4.	0.	0.	4.
SCENEDESMUS BIJUGA (18870)	1 - 3	6.	4.	2.	12.
SCENEDESMUS ACUMINATUS (18930)	1 - 3	8.	0.	13.	21.
SCENEDESMUS INTERMEDIUS (18940)	1 - 3	3.	0.	0.	3.
ULOTRICHALES					
HORMIDIUM SPP. (21750)	1 - 3	50.	83.	5.	138.
OEDOGONIALES					
OEDOGONIUM (25300)	1 - 3	0.	0.	6.	6.
ZYGNEMATALES					
COSMARIUM SPP. (29320)	1 - 3	1.	0.	0.	1.
PYRRHOPHYTA					
DINOKONTAE					
GLENODINIUM SPP. (44000)	1 - 3	0.	0.	1.	1.
CRYPTOPHYTA					
CRYPTOMONADACEAE					
CYANOMONAS AMERICANA (48660)	1 - 3	2.	0.	0.	2.
CHRYSOPHYTA					
OCHROMONADALES					
MALLOMONAS SPP. (61000)	1 - 3	2.	0.	0.	2.
BACILLARIOPHICEAE					
CENTRALES					
MELOSIRA ITALICA (63850)	1 - 3	4.	4.	4.	12.
MELOSIRA ISLANDICA (63890)	1 - 3	3.	3.	3.	9.
CYCLOTELLA MENEGHINIANA (64110)	1 - 3	11.	11.	11.	33.
CYCLOTELLA ATOMUS (64120)	1 - 3	1.	1.	1.	3.
FRAGILARIACEAE					
MERIDION CIRCULARE (70340)	1 - 3	2.	2.	2.	6.

PROJECT: TOXIC METALS PROJECT (TM) AREA: TAR CREEK, OAKLAHOMA (14) DATE: OCTOBER 31, 1980
STATION: 1 MILE N. OF OAKLAHOMA/KANSAS ST. LINE, 1 MILE WEST OF HWY 6 SUBSTATION: 511
SAMPLER TYPE: QUALITATIVE EPIPHYTON SCRAPE (29)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (60)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
BACILLARIOPHYCEAE					
EUNOTIACEAE					
EUNOTIA CURVATA (73670)	1 - 3	5.	5.	5.	15.
ACHNANTHACEAE					
ACHNANTHES LANCEOLATA (74540)	1 - 3	1.	1.	1.	3.
ACHNANTHES MINUTISSIMA (74600)	1 - 3	173.	173.	173.	519.
COCCONEIS PLACENTULA (74630)	1 - 3	1.	1.	1.	3.
NAVICULACEAE					
AMPHIPLEURA PELLUCIDA (75520)	1 - 3	2.	2.	2.	6.
FRUSTULIA RHOMBOIDES VAR. SAXONICA (76960)	1 - 3	1.	1.	1.	3.
NAVICULA SPP. (77520)	1 - 3	1.	1.	1.	3.
NAVICULA ARVENSIS (77530)	1 - 3	4.	4.	4.	12.
NAVICULA PUPULA VAR. RECTANGULARIS (77600)	1 - 3	1.	1.	1.	3.
NAVICULA MINIMA (77680)	1 - 3	1.	1.	1.	3.
NAVICULA PELLICULOSA (77700)	1 - 3	5.	5.	5.	15.
NEIDIUM AFFINE (78530)	1 - 3	2.	2.	2.	6.
PINNULARIA SPP. (78820)	1 - 3	14.	14.	14.	42.
PINNULARIA SUBCAPITATA (78850)	1 - 3	355.	355.	355.	1065.
PINNULARIA MAJOR (78920)	1 - 3	6.	6.	6.	18.
GOMPHONEMACEAE					
GOMPHONEMA PARVULUM (80510)	1 - 3	2.	2.	2.	6.
CYMBELLACEAE					
CYMBELLA MINUTA VAR. SILESIACA (81520)	1 - 3	6.	6.	6.	18.
CYMBELLA SINUATA (81530)	1 - 3	1.	1.	1.	3.
NITZSCHIACEAE					
NITZSCHIA SPP. (84000)	1 - 3	10.	10.	10.	30.
NITZSCHIA DISSIPATA (84020)	1 - 3	1.	1.	1.	3.
NITZSCHIA PALEA (84030)	1 - 3	14.	14.	14.	42.
NITZSCHIA AMPHIBIA (84070)	1 - 3	24.	24.	24.	72.
NITZSCHIA IGNORATA (84110)	1 - 3	71.	71.	71.	213.
NITZSCHIA PSEUDOAMPHIOXYS (84120)	1 - 3	20.	20.	20.	60.
SURIRELLACEAE					
SURIRELLA ANGUSTATA (85210)	1 - 3	1.	1.	1.	3.
CYANOPHYTA					
CHROOCOCCALES					
DACTYLOCOCCOPSIS RHAPIDIOIDES (88520)	1 - 3	1.	0.	2.	3.

APPENDIX C
PERIPHYTON CENSUS DATA

PROJECT: TOXIC METALS PROJECT (TM) AREA: TAR CREEK, OAKLAHOMA (14) DATE: OCTOBER 31, 1980
STATION: 1 MILE N. OF OAKLAHOMA/KANSAS ST. LINE, 1 MILE WEST OF HWY 6 SUBSTATION: S11
SAMPLER TYPE: QUALITATIVE EPIPHYTON SCRAPE (29)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (60)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
CYANOPHYTA					
OSCILLATORIALES					
OSCILLATORIA SPP. (92000)	1 - 3	69.	0.	0.	69.
MISC					
MONADS <10UM (99908)	1 - 3	9.	3.	19.	31.
SINGLE CELLS (99910)	1 - 3	6.	20.	124.	150.
TOTAL FOR 49 SPECIES BY REPLICATE:	1 - 3	948.	861.	939.	
TOTAL FOR 3 REPLICATES, 49 SPECIES:		2748.			

PROJECT: TOXIC METALS PROJECT (TM) AREA: TAR CREEK, OAKLAHOMA (14) DATE: SEPTEMBER 30, 1980
STATION: STATELINE ROAD, 1 MILE WEST OF HWY 69 (141) SUBSTATION: S11
SAMPLER TYPE: QUALITATIVE EPIPHYTON SCRAPE (29)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (60)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
CHLOROPHYTA					
CHLOROCOCCALES					
TETRAEDRON SPP. (11860)	1 - 3	1.	0.	0.	1.
KIRCHNERIELLA SPP. (14060)	1 - 3	0.	0.	1.	1.
SCENEDESMUS QUADRICAUDA (18880)	1 - 3	0.	1.	0.	1.
SCENEDESMUS ABUNDANS (18910)	1 - 3	4.	0.	0.	4.
ZYGNEMATALES					
MOUGEOTIA SPP. (26800)	1 - 3	59.	2.	16.	78.
SPIROGYRA SPP. (27320)	1 - 3	2.	0.	0.	2.
COSMARIUM SPP. (29320)	1 - 3	0.	0.	0.	0.
CRYPTOPHYTA					
CRYPTOMONADACEAE					
RHODOMONAS MINUTA VAR. NANNOPLANCTICA (48420)	1 - 3	0.	1.	0.	1.
BACILLARIOPHYCEAE					
FRAGILARIACEAE					
MERIDION CIRCULARE VAR. CONSTRICTUM (70350)	1 - 3	1.	1.	1.	3.
FRAGILARIA CROTONENSIS (70850)	1 - 3	1.	1.	1.	3.
EUNOTIACEAE					
EUNOTIA NAEGELII (73680)	1 - 3	1.	1.	1.	3.
ACHNANTHACEAE					
ACHNANTHES LANCEOLATA (74540)	1 - 3	1.	1.	1.	3.
ACHNANTHES MINUTISSIMA (74600)	1 - 3	1.	1.	1.	3.
NAVICULACEAE					
ANOMOEONEIS VITREA (75930)	1 - 3	1.	1.	1.	3.
CALONEIS VENTRICOSA VAR. ALPINA (76350)	1 - 3	1.	1.	1.	3.
NEIDIUM AFFINE (78530)	1 - 3	1.	1.	1.	3.
PINNULARIA STOMATOPHORA (78890)	1 - 3	1.	1.	1.	3.
PINNULARIA ABAUJENSIS VAR. LINEARIS (78930)	1 - 3	1.	1.	1.	3.
CYMBELLACEAE					
CYMBELLA MINUTA VAR. SILESIACA (81520)	1 - 3	1.	1.	1.	3.
NITZSCHIACEAE					
HANTZSCHIA SPP. (83420)	1 - 3	1.	1.	1.	3.
NITZSCHIA SPP. (84000)	1 - 3	1.	1.	1.	3.
NITZSCHIA PALEA (84050)	1 - 3	1.	1.	1.	3.
CYANOPHYTA					
CHROOCOCCALES					
CHROOCOCCUS SPP. (87550)	1 - 3	59.	43.	90.	192.

PROJECT: TOXIC METALS PROJECT (TM) AREA: TAR CREEK, OAKLAHOMA (14) DATE: SEPTEMBER 30, 1980
STATION: STATELINE ROAD, 1 MILE WEST OF HWY 69 (141) SUBSTATION: 511
SAMPLER TYPE: QUALITATIVE EPIPHYTON SCRAPE (79)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (60)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
CYANOPHYTA					
OSCILLATORIALES					
LYNGBYA SPP. (91520)	1 - 3	173.	80.	0.	253.
OSCILLATORIA SPP. (92000)	1 - 3	48.	0.	40.	88.
PHORMIDIUM SPP. (93000)	1 - 3	0.	37.	90.	127.
TOTAL FOR 26 SPECIES BY REPLICATE:	1 - 3	357.	179.	251.	
TOTAL FOR 3 REPLICATES, 26 SPECIES:		787.			

PROJECT: TOXIC METALS PROJECT (TM) AREA: TAR CREEK, OAKLAHOMA (14) DATE: OCTOBER 30, 1980
STATION: 0.25 MILES S STATELINE ROAD, 1 MILE WEST OF HWY 69 (142) SUBSTATION: 511
SAMPLER TYPE: QUALITATIVE EPIPHYTON SCRAPE (29)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (60)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
CHLOROPHYTA					
ULOTRICHALES					
HORMIDIUM SPP. (21750)	1 - 3	60.	75.	52.	187.
ULOTHRIX SPP. (22170)	1 - 3	363.	1038.	408.	1809.
ZYGNEMATALES					
MOUGEOTIA SPP. (26800)	1 - 3	25.	10.	30.	65.
BACILLARIOPHYCEAE					
FRAGILARIACEAE					
DIATOMA HIEMALE VAR. MESODON (70330)	1 - 3	1.	1.	1.	3.
SYNEDRA RUMPENS (72120)	1 - 3	6.	6.	6.	18.
SYNEDRA ACUS (72240)	1 - 3	1.	1.	1.	3.
HANNAEA ARCUS VAR. AMPHIOXYS (73120)	1 - 3	1.	1.	1.	3.
EUNOTIACEAE					
EUNOTIA SPP. (73620)	1 - 3	2.	2.	2.	6.
ACHNANTHACEAE					
ACHNANTHES LANCEOLATA (74540)	1 - 3	1.	1.	1.	3.
ACHNANTHES LINEARIS (74570)	1 - 3	38.	38.	38.	114.
ACHNANTHES MINUTISSIMA (74600)	1 - 3	259.	259.	259.	777.
NAVICULACEAE					
ANOMOEONEIS VITREA (75930)	1 - 3	288.	288.	288.	864.
PINNULARIA STOMATOPHORA (78890)	1 - 3	1.	1.	1.	3.
GOMPHONEMACEAE					
GOMPHONEMA PARVULUM (80510)	1 - 3	1.	1.	1.	3.
CYMBELLACEAE					
CYMBELLA MINUTA VAR. SILESIACA (81520)	1 - 3	96.	96.	96.	288.
NITZSCHIACEAE					
HANTZSCHIA AMPHIOXYS (83430)	1 - 3	1.	1.	1.	3.
NITZSCHIA DISSIPATA (84020)	1 - 3	1.	1.	1.	3.
TOTAL FOR 17 SPECIES BY REPLICATE:	1 - 3	1145.	1820.	1187.	
TOTAL FOR 3 REPLICATES, 17 SPECIES:		4152.			

PROJECT: TOXIC METALS PROJECT (TM) AREA: TAR CREEK, OAKLAHOMA (14) DATE: SEPTEMBER 30, 1980
STATION: PICHER HIGH SCHOOL ROAD, 0.46 MILES WEST OF HWY 69 (143) SUBSTATION: 921
SAMPLER TYPE: QUALITATIVE EPIPHYTON SCRAPE (29)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (60)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
CHLOROPHYTA					
VOLVOCALES					
CHLAMYDOMONAS SPP. (1870)	1 - 3	12.	16.	22.	50.
SCOURFIELDIA CORDIIFORMIS (6770)	1 - 3	4.	5.	0.	9.
CHLOROCOCCALES					
SPHAEROCYSTIS SCHROETERI (13170)	1 - 3	0.	4.	0.	4.
OOCYSTIS SPP. (15210)	1 - 3	10.	2.	0.	12.
SELENASTRUM SPP. (16010)	1 - 3	1.	1.	0.	2.
ZYGNEMATALES					
MOUGEOTIA SPP. (26800)	1 - 3	29.	10.	9.	48.
EUGLENOPHYTA					
EUGLENALES					
EUGLENA ACUS (37010)	1 - 3	0.	0.	1.	1.
CRYPTOPHYTA					
CRYPTOMONADACEAE					
RHODOMONAS MINUTA VAR. NANNOPLANCTICA (48420)	1 - 3	1.	2.	1.	4.
CYANOMONAS AMERICANA (48660)	1 - 3	33.	31.	19.	83.
CHRYSOPHYTA					
OCHROMONADALES					
OCHROMONAS SPP. (58120)	1 - 3	2.	0.	2.	4.
BACILLARIOPHYCEAE					
FRAGILARIACEAE					
SYNEDRA SPP. (72110)	1 - 3	1.	1.	1.	3.
ACHNANTHACEAE					
ACHNANTHES MINUTISSIMA (74600)	1 - 3	16.	16.	16.	48.
CYMBELLACEAE					
CYMBELLA MINUTA (81510)	1 - 3	1.	1.	1.	3.
CYANOPHYTA					
OSCILLATORIALES					
PHORMIDIUM SPP. (93000)	1 - 3	0.	21.	25.	46.
MISC					
MONADS <10UM (99900)	1 - 3	55.	1.	0.	56.
SINGLE CELLS (99910)	1 - 3	6.	0.	0.	6.
TOTAL FOR 16 SPECIES BY REPLICATE:	1 - 3	171.	111.	97.	
TOTAL FOR 3 REPLICATES, 16 SPECIES:		379.			

PROJECT: TOXIC METALS PROJECT (TM) AREA: TAR CREEK, OAKLAHOMA (14) DATE: SEPTEMBER 30, 1980
STATION: CARDIN ROAD AT CARDIN (144) SUBSTATION: 521
SAMPLER TYPE: QUALITATIVE EPIPHYTON SCRAPE (29)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (60)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
CHLOROPHYTA					
VOLVOCALES					
CARTERIA GLOBOSA (870)	1 - 3	4.	0.	7.	11.
CHLAMYDOMONAS SPP. (1870)	1 - 3	3.	1.	9.	13.
SCOURFIELDIA CORDIIFORMIS (6770)	1 - 3	1.	8.	0.	9.
CHLOROCOCCALES					
SCENEDESMUS BIJUGA (18870)	1 - 3	2.	2.	0.	4.
SCENEDESMUS DENTICULATUS (18900)	1 - 3	0.	3.	0.	3.
SCENEDESMUS ABUNDANS (18910)	1 - 3	0.	4.	0.	4.
SCENEDESMUS ACUMINATUS (18930)	1 - 3	0.	4.	0.	4.
ULOTRICHALES					
ULOTHRIX SPP. (22170)	1 - 3	45.	85.	34.	164.
ZYGNEMATALES					
MOUGEOTIA SPP. (26800)	1 - 3	0.	8.	0.	8.
EUGLENOPHYTA					
EUGLENALES					
EUGLENA SPP. (37000)	1 - 3	0.	1.	0.	1.
TRACHELOMONAS SPP. (38000)	1 - 3	7.	7.	6.	20.
CRYPTOPHYTA					
MONADS <10UM (47020)	1 - 3	0.	2.	0.	2.
CRYPTOMONADACEAE					
CHILOMONAS SPP. (47500)	1 - 3	0.	0.	1.	1.
CRYPTOMONAS OVATA (47930)	1 - 3	0.	2.	0.	2.
-ALL- (48010)	1 - 3	6.	0.	0.	6.
RHODOMONAS MINUTA VAR. NANNOPLANCTICA (48420)	1 - 3	0.	0.	1.	1.
CYANOMONAS AMERICANA (48660)	1 - 3	54.	37.	72.	163.
CHRYSOPHYTA					
OCHROMONADALES					
OCHROMONAS SPP. (58120)	1 - 3	1.	1.	0.	2.
MALLOMONAS SPP. (61000)	1 - 3	0.	0.	1.	1.
BACILLARIOPHYCEAE					
CENTRALES					
CYCLOTELLA MENEGHINIANA (64110)	1 - 3	2.	2.	2.	6.
FRAGILARIACEAE					
SYNEDRA SPP. (72110)	1 - 3	1.	1.	1.	3.

PROJECT: TOXIC METALS PROJECT (TM) AREA: TAR CREEK, OAKLAHOMA (14) DATE: SEPTEMBER 30, 1980
STATION: CARDIN ROAD AT CARDIN (144) SUBSTATION: S21
SAMPLER TYPE: QUALITATIVE EPIPHYTON SCRAPE (29)
NUMBER OF REPLICATES: 3 FIELD BIOLOGIST: KEN MOOR (60)
NOTE: NOT APPLICABLE (0)

RAW DATA TABLES

1ST LEVEL REFERENCE / 2ND LEVEL REFERENCE / GENUS/SPECIES	REPLICATES	COUNTS			TOTAL FOR SP.
BACILLARIOPHYCEAE					
FRAGILARIACEAE					
SYNEDRA SOCIA (72190)	1 - 3	1.	1.	1.	3.
SYNEDRA ULNA VAR. AMPHIRHYNCHUS (72250)	1 - 3	1.	1.	1.	3.
EUNOTIACEAE					
EUNOTIA CURVATA (73670)	1 - 3	4.	4.	4.	12.
ACHNANTHACEAE					
ACHNANTHES MINUTISSIMA (74600)	1 - 3	9.	9.	9.	27.
NAVICULACEAE					
CALONEIS BACILLUM (76330)	1 - 3	1.	1.	1.	3.
CALONEIS VENTRICOSA VAR. TRUNCATULA (76360)	1 - 3	2.	2.	2.	6.
NAVICULA SPP. (77520)	1 - 3	1.	1.	1.	3.
NAVICULA ARVENSIS (77530)	1 - 3	2.	2.	2.	6.
PINNULARIA SPP. (78820)	1 - 3	2.	2.	2.	6.
PINNULARIA MICROSTAURON (78880)	1 - 3	2.	2.	2.	6.
GOMPHONEMACEAE					
GOMPHONEMA PARVULUM (80510)	1 - 3	1.	1.	1.	3.
NITZSCHIACEAE					
NITZSCHIA SPP. (84000)	1 - 3	2.	2.	2.	6.
NITZSCHIA ACICULARIS (84010)	1 - 3	1.	1.	1.	3.
NITZSCHIA FILIFORMIS (84140)	1 - 3	2.	2.	2.	6.
CYANOPHYTA					
CHROOCOCCALES					
DACTYLOCOCCOPSIS RHAPIDIOIDES (88520)	1 - 3	2.	5.	4.	11.
MISC					
MONADS <10UM (99900)	1 - 3	5.	11.	11.	27.
SINGLE CELLS (99910)	1 - 3	0.	0.	3.	3.
TOTAL FOR 38 SPECIES BY REPLICATE:	1 - 3	164.	215.	183.	
TOTAL FOR 3 REPLICATES, 38 SPECIES:		562.			

APPENDIX D
TISSUE METAL ANALYSIS SUMMARY DATA

MEAN ZINC CONCENTRATIONS (ppm), TAR CREEK, OK, IN VARIOUS PLANT TISSUES.
MEANS ARE BASED ON THREE ANALYTICAL REPLICATES UNLESS OTHERWISE INDICATED.

Station	Roots	Leaves and Stems	Whole Plant
145	3368.4	2603.8	2063.6
	2270.7	30100.0	
	2353.7	4860.8	
		1477.3	
		14000.0	
141	7285.2	1642.9	6244.0
	11756.3	622.4	4934.3
			1316.9
			14300.0
			23600.0
			5353.4
142	13500.0	1674.6	3999.3
	17400.0	2007.4	14800.0
	30700.0		21400.0
			11471.7
143	18600.0	3562.9	24800.0
	11132.8	2752.9	M
	15000.0	4318.8	
	21708.1	28200.0	
	M	M	
		10560.0	
144	13600.0	13800.0	16400.0
	6382.8	7750.5	11200.0
	19100.0	2268.4	3924.7
	27300.0	4339.9	16461.2
	4530.4	1858.2	3570.0
	27000.0	23800.0	21900.0
			17596.0
			16300.0

M = Concentrations exceed maximum instrumentation detection limits (of one or more replicates).

MEAN CADMIUM CONCENTRATIONS (ppm), TAR CREEK, OK, IN VARIOUS PLANT TISSUES. MEANS ARE BASED ON THREE ANALYTICAL REPLICATES UNLESS OTHERWISE INDICATED.

Station	Roots	Leaves and Stems	Whole Plant
145	7.2K	ND**	3.8K
	6.2	4.9	
		ND	
		4.7K*	
141	4.3K	ND	ND
			ND*
			ND*
			11.2
			13.2
			ND*
142	8.8K	4.4	4.4K
	36.5	4.9	10.1
			13.3
			9.4
143	17.0	4.2K	14.2
	22.9	ND	30.4
	33.7	5.5	
	ND	43.9	
	92.4	48.4	
144	ND	7.4	6.0
	10.6	ND	4.4K
	28.6	ND**	ND**
	ND	ND*	3.9K
	24.7	ND	5.1K
		16.5	ND
			14.8

* = 2 replicates only.
** = 1 replicate only.
ND = not detectable.
K = value known to be less than indicated.

MEAN SILVER CONCENTRATIONS (ppm), TAR CREEK, OK, IN VARIOUS PLANT TISSUES. MEANS ARE BASED ON THREE ANALYTICAL REPLICATES UNLESS OTHERWISE INDICATED.

Station	Roots	Leaves and Stems	Whole Plant
145		ND**	
141			
142	ND** 0.2**		0.5K* 0.9
143	0.2*	0.2	
144	0.8	ND**	

* = 2 replicates only.
** = 1 replicate only.
K = value known to be less than indicated.
ND = not detectable.

MEAN LEAD CONCENTRATIONS (ppm), TAR CREEK, OK, IN VARIOUS PLANT TISSUES. MEANS ARE BASED ON THREE ANALYTICAL REPLICATES UNLESS OTHERWISE INDICATED.

Station	Roots	Leaves and Stems	Whole Plant
145	125.3	ND**	
	14.1	372.1	
		27.1	
		208.7	
		59.4	
141	43.9	ND**	22.9
	322.0	11.4**	7.1
			88.6
			128.8
			28.7
142	1833.7		18.0
	537.4		253.4
	2294.4		353.9
			52.8
143	2562.5	1.3**	532.1
	2094.9	1.6K*	1415.8
	2966.6	39.2	
	207.5	56.2	
	1664.8	1334.4	
		1791.8	
144	160.3	8.6	39.8
	286.7	92.9	22.4
	1631.9	11.8	30.5
	3232.5M	51.9	233.6
	1.8K*	1.5K*	143.8
	2104.9	2325.2	266.0
			135.6
			347.2

* = 2 replicates only.
** = 1 replicate only.
ND = not detectable.
K = value known to be less than indicated.
M = Concentrations (of one or more replicates) exceeding maximum instrumentation detection limits.

MEAN NICKEL CONCENTRATIONS (ppm), TAR CREEK, OK, IN VARIOUS PLANT TISSUES. MEANS ARE BASED ON THREE ANALYTICAL REPLICATES UNLESS OTHERWISE INDICATED.

Station	Roots	Leaves and Stems	Whole Plant
145	8.7	3.7	ND*
	1.6		0.9K*
141	2.2	1.8	1.3
	5.7	ND	1.6*
			0.8K*
			8.2
			13.7
			3.3
142	18.9	1.3	2.6
	11.5	0.9**	19.5
	23.3		30.8
			15.6
143	17.4	2.0	9.9
	16.1	0.9	62.2
	4.2	2.0	
	47.7	1.9	
		79.4	
		19.1	
144	40.2	1.4	4.1
	10.2	1.0	3.7
	14.5	18.4	2.8
	16.2	5.5	10.4
	0.8K*	1.4	15.1
	2.3	4.6	9.4
	1.6	23.1	12.8

* = 2 replicates only.
** = 1 replicate only.
K = value known to be less than indicated.

MEAN ZINC CONCENTRATIONS (ppm), TAR CREEK, OK, IN VARIOUS FISH TISSUES. MEANS ARE BASED ON THREE ANALYTICAL REPLICATES UNLESS OTHERWISE INDICATED.

Station	Brain	Gill	Liver	Muscle	Kidney	Eyes	Heart	Stomach
145	79.9	313.0	183.9	55.6		620.4		
141	168.4	977.3	1811.9	60.7		691.9		
	131.1*	911.4	505.0	47.8		702.0		
142								
143								
144	89.8	643.9	225.2	42.9	148.1*	417.0	164.0	304.7

* = 2 replicates only.

MEAN CADMIUM CONCENTRATIONS (ppm), TAR CREEK, OK, IN VARIOUS FISH TISSUES. MEANS ARE BASED ON THREE ANALYTICAL REPLICATES UNLESS OTHERWISE INDICATED.

Station	Brain	Gill	Liver	Muscle	Kidney	Eyes	Heart	Stomach
145	ND**	6.9**	28.7	ND*				
141	ND	5.8	6.7	ND		ND*		
		ND	3.9K	ND				
142								
143								
144		3.8K	13.8	ND		ND	12.9	3.8K

* = 2 replicates only.
** = 1 replicate only.
ND = not detectable (concentration below minimum detection limits).

MEAN SILVER CONCENTRATIONS (ppm), TAR CREEK, OK, IN VARIOUS FISH TISSUES. MEANS ARE BASED ON THREE ANALYTICAL REPLICATES UNLESS OTHERWISE INDICATED.

Station	Brain	Gill	Liver	Muscle	Kidney	Eyes	Heart	Stomach
145			ND**			ND*		
141	0.4	0.5	0.4K	ND**		0.5		
	ND**	0.2**	0.2K	ND**		0.4		
142								
143								
144	0.3K	0.4*	ND*		0.2**	0.4	0.3K	0.2*

* = 2 replicates only.
** = 1 replicate only.
K = Value known to be less than indicated.
ND = Not detectable (concentration below minimum detection limits).

MEAN LEAD CONCENTRATIONS (ppm), TAR CREEK, OK, IN VARIOUS FISH TISSUES. MEANS ARE BASED ON THREE ANALYTICAL REPLICATES UNLESS OTHERWISE INDICATED.

Station	Brain	Gill	Liver	Muscle	Kidney	Eyes	Heart	Stomach
145		40.1				8.4*		
141		94.7	5.3			5.2*		
		59.6	1.8			3.0*		
142								
143								
144		37.0				ND**	7.0	12.6

* = 1 replicate only.

MEAN NICKEL CONCENTRATIONS (ppm), TAR CREEK, OK, IN VARIOUS FISH TISSUES. MEANS ARE BASED ON THREE ANALYTICAL REPLICATES UNLESS OTHERWISE INDICATED.

Station	Brain	Gill	Liver	Muscle	Kidney	Eyes	Heart	Stomach
145	0.9*	6.2	0.8K	1.3		2.9		
141	2.5	6.3	1.1	1.4		2.0		
	0.9K*	7.9	1.0	ND*		2.1		
142								
143								
144	1.4	8.6	1.4**	0.8**	0.8**	1.3	1.5*	1.4*

* = 2 replicates only.
** = 1 replicate only.
K = Value known to be less than indicated.

APPENDIX E

SUMMARIZED BIOASSAY RESULTS: DULUTH

COMPARISON OF FOUR TOXIC RESPONSES TO 30 AMBIENT WATER SAMPLES. Sample numbers relate to stations from 15 rivers sampled during the 1980 toxic metals project.

	Sample Number	*Daphnia* Toxicity	Enzyme Inhibition	Fish Ventilation Index	Algal Toxicity
	011				
	013	+	+	+	+
	021	+	+		+
	023		+		
	034				
	035	+	+		+
	042		+		
	045		+	+	
	051				
	054				+
	061		+		
	066		+		+
	073		+	ND*	+
	074		+	ND	
	081	+			+
	082	+	+	+	+
	092		+	+	
	094	+	+	+	+
	012	+		+	
	103	+		+	+
	111				
	114				
	121			+	
	122			+	+
	132				
	133	+		+	+
Tar Creek	142	+		ND**	+
	143	+		ND**	+
	161		+		
	162				

\+ Positive response indicated.
* No data.
** Stress evident but unable to quantify.