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INVESTIGATION OF TRACE ELEMENT CONTAMINATION FROM TERREROMINE WASTE

FISH AND WILDLIFE SERVICE

U.S. DEPARTMENT OF THE INTERIOR

Investigation of Trace Element Contamination From Terrero Mine Waste San Miguel County, New Mexico

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Abstract

Thirty-eight biological samples from the Terrero Mine Waste study area were analyzed for 23 inorganic compounds. This analysis was conducted because of the potential contamination of fish and wildlife habitat and concern for human exposure from toxic levels of inorganic compounds. The Terrero Mine land surface consists of numerous unstabilized spoil and overburden piles which produce surface runoff to the Pecos River. Mine spoil material was used to construct a portion of New Mexico Highway 63 and campground features at Willow Creek, Terrero, Jack's Creek, and Panchuela campgrounds. Mammal samples collected consisted of individual and composite liver and kidney tissues from least chipmunk, golden-mantled ground squirrel, and deer mouse. Fish samples consisted of individual edible portion fillet and composite whole-body tissue from rainbow and brown trout. One sample of liver and kidney tissues from brown trout was collected. Prior to analysis, all samples were homogenized and aliquots were freeze-dried to determine moisture content. Inductively Coupled Plasma (ICP) Emission measurement was conducted after acid preconcentration for 19 elements. A separate digestion for arsenic, lead, mercury, and selenium was done and Graphite Furnace Atomic Absorption measurements were made for arsenic, lead, and selenium. Analysis of mercury wae by Cold Vapor Atomic Absorption. Of the 23 element5 that were analyzed, 16 elements were either not detected or were detected at normal background levels compared to geochemical baseline values and residue levels in similar samples from New Mexico. The seven elements that exceeded either background or residue data from biological samples collected in New Mexico were arsenic, cadmium, copper, lead, zinc, mercury, and selenium. Of these seven elements, copper, zinc, selenium, and lead were elevated in biological samples. The maximum level of copper in deer mice was 6.9 ug/g wet weight (wwt) and in brown trout 3.38 ug/g wwt. The maximum levels of zinc detected were 33.97 ug/g wwt in golden-mantled ground squirrels and 20.88 ug/g wwt in brown trout. Above Lisboa Springs Hatchery, higher zinc residues were noted in brown trout tissue. Environmental concern or human health residue levels have not been established for copper or zinc. The maximum level of selenium in deer mice was 1.53 mg/g wwt and in brown trout was 6.62 ug/g wwt. Selenium level5 exceeded predator protection limits. Lead residues in both mammal and fish tissue were elevated in the study area. The maximum lead concentration of 3.79 ug/g wwt in deer mice was considerably higher than reference data in similar species. Whole-body residue level5 in fish, with a maximum value of 1.45 ug/g wwt and a mean of 1.0 ug/g wwt, were above the 85th percentile and geometric mean of the National Contaminant Biomonitoring Program (NCBP) data. Maximum lead residues in edible portion fish tissue (0.27 ug/g wwt) are near the human consumption criterion (greater than 0.3 ug/g). Lead residues in small mammal tissue exceeded the protection criterion of 0.05 mg/kg for prey items of raptors. Selenium and lead residues in whole-body and liver and kidney portion5 of mammals, a5 well as whole-body and edible portion fillet5 from larger fish, should be investigated.

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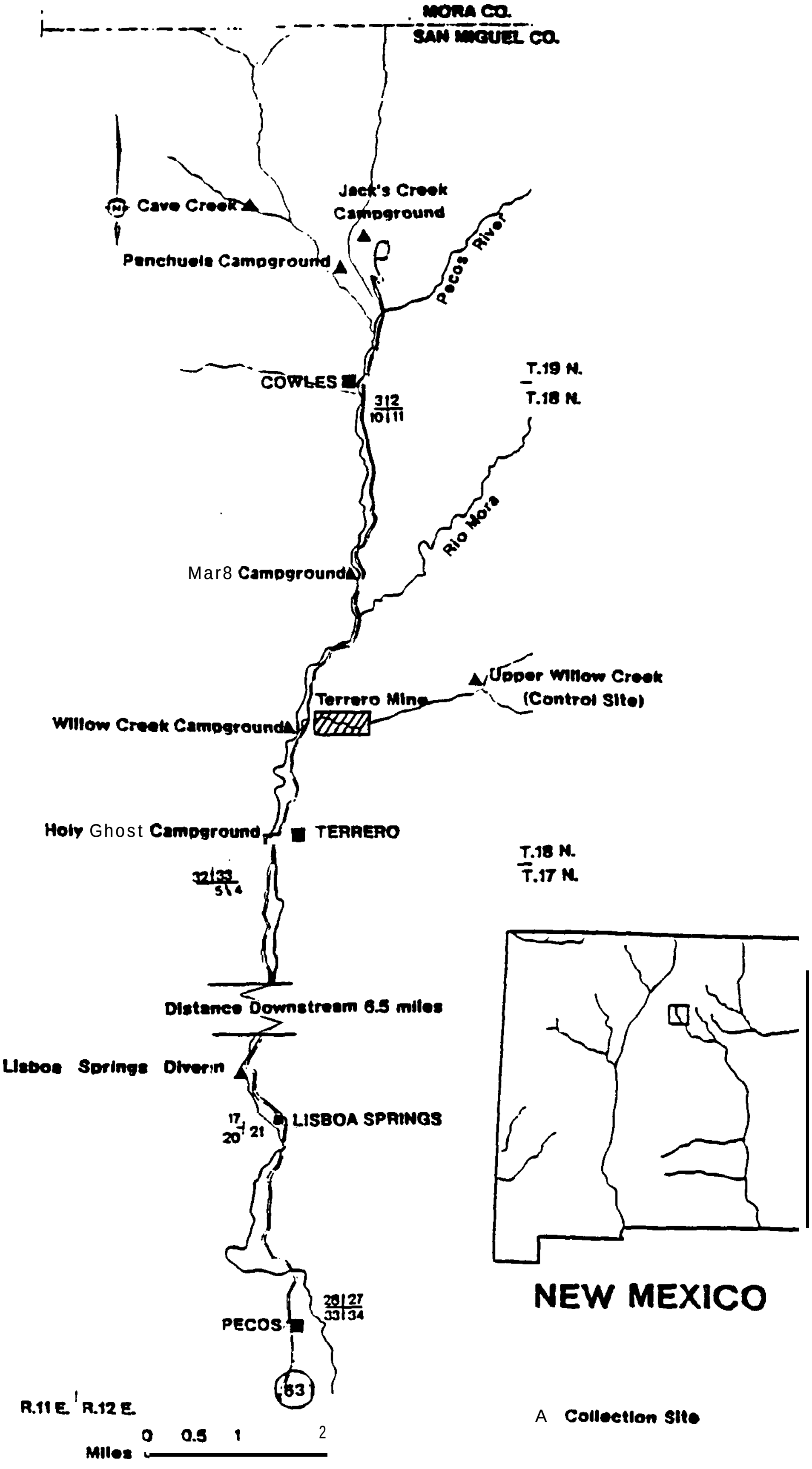
Introduction

The New Mexico Department of Game and Fish (NMDG&F) Lisboa Springs Fish Hatchery is located adjacent to the Pecos River upstream from Pecos, New Mexico. Water for the hatchery is supplied exclusively by the Pecos River. In the past, the hatchery has experienced major fish die-offs coincident with rainfall events in the basin. Changes in water chemistry and pH as a result of these rainfall events may be one cause for these die-offs. Toxic effects from trace elements are also suspected to trigger fish mortalities. A potential source of material that may produce water chemistry perturbations is the Terrero Mine which is located approximately 11.5 miles upstream from the hatchery (Figure 1). The Pecos River upper basin, which encompasses the Terrero Mine, is within the general administrative boundaries of the Santa Fe National Forest. The 19-acre abandoned Terrero Mine once produced copper, zinc, lead, silver, and gold. It is approximately 1.75 miles north of Terrero, New Mexico, at the confluence of Willow Creek and the Pecos River. The surface of the mine is primarily within the NMDG&F Bert Clancey Fish and Wildlife Area. The mine surface consists of numerous spoil and overburden piles that have not been stabilized. Materials from the mine have been used to construct portions of the roadbed for New Mexico Highway 63 and to construct roads and pads at the Willow Creek, Terrero, Jack's Creek, and Panchuela campgrounds. Willow Creek flows across a portion of the mine piles near the Pecos River confluence. Panchuela and Willow Creek campgrounds were closed by their respective agencies until questions regarding human health exposure could be answered (NMEID 1990).

Site investigations were developed to identify hazardous materials from the Terrero Mine and campgrounds adjacent to the Pecos River and Willow Creek. These site investigations are joint projects of the U.S. Forest Service (USFS), NMDG&F, and New Mexico Health and Environment Department, Environmental Improvement Division (NMEID), and may be used under the authority of the Comprehensive Environmental Response, Compensation and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act of 1986 (SARA) to determine if the Terrero Mine is eligible for the National Priorities List. Preliminary site investigations involved analysis of 29 water quality parameters by the NMEID in the Pecos River and Willow Creek and analysis of sediment soil for five trace elements, sulfates, and hydrogen sulfide by Radian Corporation for the USFS. Fish samples were collected by the NMDG&F, USFS, and U.S. Fish and Wildlife Service (USFWS) and were analyzed by the USFS and USFWS for 23 trace elements. Small mammals collected by the USFS, NMEID, and USFWS at the campgrounds were analyzed for the same 23 elements by the USFS.

Data for water quality in the upper Pecos River Basin are limited. In 1982, NMEID conducted an analytical study of water quality of this portion of the Pecos River Basin. The report generated by that study indicated that the concentration values for most metals were low, although barium, cadmium, manganese, and copper were slightly elevated in Willow Creek (NMEID 1982).

FIGURE 1: Terrero Mine Waste study area and collection sites, 1990



The USFWS collected biological samples in the Pecos River at Santa Rosa Reservoir in 1989. Fish samples from this site, located approximately 100 miles downstream from Pecos, New Mexico, indicated that residues of mercury and selenium were above the geometric mean from the NCBP (Lowe et al. 1985).

Study Area

The Pecos River originates in the Santa Fe National Forest at more than 13,000 feet above mean sea level (MSL) in the Truchas Peak area of the Sangre de Cristo Mountains of New Mexico. From its headwaters at the Santa Barbara Divide, the Pecos River descends through granite canyons and open meadows in the Pecos Wilderness. Below the Wilderness boundary, the Pecos River enters a broad section of the canyon. At high elevations in the wilderness, vegetation is dominated by Englemann spruce interspersed with aspen and corkbark fir. At lower elevations, ponderosa pine, Douglas fir, white fir, limber pine, bristle-cone pine, and aspen occur. Riparian vegetation is dominated by Fremont cottonwood (USFS 1987).

The upper Pecos River is a popular recreational area used by anglers, hikers, and campers. The Pecos River and its tributaries within the study area are aggregately managed as a high-quality coldwater fishery. There are several campgrounds adjacent to the river and its tributaries. Campgrounds managed by the USFS include Iron Gate, Jack's Creek, Windy Bridge, Panchuela, Windsor Creek, and Holy Ghost. The NMDG&F manage5 the Bert Clancey Fish and Wildlife Area which includes the Willow Creek, Mora, and Terrero campground5 (USFS 1987).

The climate in the study area at Cowles, New Mexico, tends to be subhumid at 8,000 feet MSL and above. The average annual precipitation is 23.74 inches and temperature5 range from lows of -27" F to 90" F with an average temperature of 42°F. The average annual snowfall is 81 inches.

Sample Area and Methods

Biological sample5 have been collected at several locations in the Terrero Mine Waste study area (Figure 1). The study area locations will be referred to a5 the Terrero area in this report. Fish were collected at two locations on the Pecos River and at one location on Cave Creek. The fish sample5 from the Pecos River were collected in May 1990 and the fish from Cave Creek were collected in September 1990. Fish were collected using a backpack electroshocker. Individual fillet5 were removed from the left side of each fish and packaged in a ziplock bag. A stainless steel fillet knife was used to remove each fillet, and the knife was washed and rinsed in distilled water after each sample. Composite whole-body fish samples were placed in ziplock bags. Care was taken with all samples to avoid contact with contaminated surfaces. Samples were placed on ice and frozen within 2 hour5 of collection.

Small mammals were collected at three campground5 and a control site in the Terrero area in September 1990. The collection site5 were Panchuela, Jack's Creek, and Willow Creek campgrounds (Figure 1). The control site was located near the headwaters of Willow Creek. Collections were made using Sherman live traps, Hav-a-Hart, and air rifles. Specimens were euthanized and then dissected to remove liver and kidney tissues for analyses. The liver and kidneys were removed from each specimen, placed in ziplock bags, and frozen immediately. Sterile stainless steel dissection tools were used to avoid the introduction of trace elements, and dissections were performed on a sterile surface. Dissection tools were decontaminated between specimens to avoid cross-contamination of samples. The list of species collected and sample site locations are shown in Table 1. Sample analyses were conducted on mammal liver and kidney tissues, fish edible portion, fish whole-body, and one sample of fish liver and kidney for the 23 trace elements listed in Table 2.

Table 1. Biological Samples and Collection Locations From the Terrero Mine Waste Study Area.

Collection Site	Specie5		Number of Samples
	MAMMALS		Liver/Kidney
Panchuela Campground	*Peromyscus maniculatus*		4
	Spermophilus lateralis		2
Jack's Creek Campground	*P. maniculatus*		3
	S. lateralis		3
	Eutamias minimus		3
Willow Creek Campground	*P. maniculatus*		1
	S. lateralis		4
	E. minimus		1
Upper Willow Creek Control	*P. maniculatus*		3
			24
	FISH		
Pecos River, Above Mora Campground	*Oncorhynchus mykiss*	Fillet	5
		Whole-body	1
Pecos River, Above Lisboa Springs Hatchery	*Salmo trutta*	Fillet	5
		Whole-body	1
Cave Creek, Above Panchuela Campground	*S. trutta*	Fillet	1
		Liver/Kidney	1
			14
Total Sample5			38

All sample5 were analyzed by Research Triangle Institute (RTI), Research Triangle Park, North Carolina. Samples were homogenized and aliquots were freeze-dried to determine moisture content. Tissue samples were preconcentrated by acid digestion prior to Inductively Coupled Plasma (ICP)

Emission measurement using a Plasma Spec I sequential spectrometer. Analysis by ICP provided results for 19 trace elements. Detection limits for these elements varied between samples due to different analytical protocol requests from the USFWS and USFS (Table 2). A separate digestion for arsenic, lead, mercury, and selenium was conducted. Graphite Furnace Atomic Absorption (GFAA) measurements were done for arsenic, lead, and selenium. Analysis of mercury residues was by Cold Vapor Atomic Absorption (CVAA) spectrophotometer. Quality control assurance for sample analysis was provided by RTI and confirmed by Patuxent Wildlife Research Center for USFWS samples. Duplicate sample and spike sample analysis was adequate, and precision was within the 95 percent confidence interval. Sample analysis provided by RTI for the USFS was also subject to the same quality control assurance. Recovery rates for ICP ranged from 87.5 percent to 110 percent of expected for all elements and duplicate sample analysis was within the 95 percent confidence interval for two limits of detection.

Table 2. Trace Elements Analyzed for Biological Samples, Trace Element Abbreviations, and Detection Limits in Dry Weight.

Element	Abbreviation	Detection Limits' Mammal ug/g	Fish ug/g
Aluminum	Al	20.0	3.0
Antimony	Sb	20.0	5.0
Barium	Ba	1.0	0.5
Beryllium	Be	0.2	0.1
Boron	B	2.0	0.5
Cadmium	Cd	0.5	0.15
Cobalt	co	3.0	0.5
Chromium	Cr	3.0	0.5
Copper	cu	3.0	0.5
Iron	Fe	10.0	10.0
Lead	Pb	5.0	1.0 (0.2)[2]
Magnesium	Mg	10.0	20.0
Manganese	Mn	2.0	0.3
Molybdenum	Mo	5.0	0.8
Nickel	Ni	4.0	0.8
Silver	Ag	5.0	1.5
Strontium	Sr	2.0	0.5
Tin	Sn	20.0	5.0
Vanadium	V	0.5	0.5
Zinc	Zn	3.0	1.0
Arsenic	As	0.3	0.3
Mercury	Hg	0.02	0.02
Selenium	Se	0.3	0.3

'Includes two fish samples: one composite trout whole-body and one composite fish liver and kidney.
*Lead detection limit 0.2 in Fish and Wildlife Service samples.

Results

Thirty-eight biological samples were submitted for analysis for this study to evaluate potential contaminant levels of trace elements in the Terrero area. These samples consisted of composite samples of liver and kidney removed from least chipmunk, deer mouse, brown trout and rainbow trout, and brown trout whole-body. Individual analysis on liver and kidney tissue was done for golden-mantled ground squirrel and edible portion fillets from rainbow and brown trout. The results of these analyses for 23 trace elements are shown in Table 3 in dry weight (dwt).

To evaluate the significance of detected residue levels for the 23 elements in biological samples from the Terrero area, the results were compared to geochemical baseline values in soils from Shacklette and Boerngen (1984) and dwt values from samples collected from the Rio Grande. Locations of the Rio Grande sites are shown in Figure 2. These samples were collected from 1985 through 1987 and the analyses and species were similar (Table 4) (Roy and O'Brien 1991).

Research concerning heavy metal residue in tissue is a recent means of evaluating contamination. Background data collection or biological effect research has not been conducted on most trace elements. By comparing detected residue levels of the 23 trace elements in this study with a database from New Mexico, an assessment of elevation of a particular metal can be made. The geochemical baseline value also provides an indication of the relative abundance of a particular element in the environment. Based upon the comparisons shown in Table 5, the following trace elements are at or below baseline or background levels and will not be evaluated further: aluminum, antimony, barium, beryllium, boron, cobalt, chromium, iron, magnesium, manganese, molybdenum, nickel, silver, strontium, tin, and vanadium. Seven trace elements were elevated to some degree in biological samples from the Pecos River and the adjacent campground areas. These seven elements will be further evaluated, including cadmium, copper, lead, zinc, arsenic, mercury, and selenium. Residue levels of these elements are usually discussed in the literature in fresh or wwt residue values. Wet weight values for these seven elements in samples from the Pecos River are shown in Table 6, and comparative residue levels in ug/g wwt in samples from the Rio Grande are shown in Table 7. Statistical tests of the significance between sites was not possible due to the collection of different species at the sites or small sample sizes.

Arsenic

Arsenic is a nonmetallic element which is often a by-product of copper and lead smelting or gold and silver recovery from ore (National Research Council [NRC] 1980). The National Academy of Science indicates that arsenic may be an essential trace element with beneficial effects similar to those of antibiotics. There are many different compounds of arsenic which may occur in either trivalent or pentavalent form (Goyer 1986).

Fish and mammals from the Terrero area exhibit arsenic residues below those reported to be indicative of arsenic contamination. Concentrations of arsenic in most samples from the study area were at or below 0.3 ug/g wwt. For small mammals, very little data are available on normal residues of arsenic. Eisler (1988b) reported that episodes of wildlife poisoning are infrequent and that mammal tissue usually contains less than 0.3 ug/g wwt. Eisler reported that background arsenic concentrations in living organisms are usually less than 1 ug/g wwt in terrestrial plants, resident wildlife, birds, and aquatic biota. The least chipmunk samples at Jack's Creek campground had residues above 0.3 ug/g wwt, with a maximum level of 1.83 ug/g wwt in an individual liver/kidney sample. By comparison, arsenic residues in rodent species from the Rio Grande ranged from less than 0.05 to 0.10 ug/g wwt.

The maximum concentration of arsenic detected in fish from the Pecos River was 0.3 ug/g wwt. Residues in whole-body fish, edible portion fillet, and fish liver and kidney were similar, suggesting that the arsenic forms present are rapidly excreted (NRC 1980). Brown trout and rainbow trout samples from the Rio Grande basin exhibited arsenic residues up to 0.53 ug/g wwt (Table 7). Schmitt and Brumbaugh (1990) reported arsenic residues in all species of fish from the United States in 1984 ranging up to 1.5 ug/g wwt (Table 8). The geometric mean of all samples of fish for the NCBP was 0.14 ug/g wwt versus 0.173 ug/g wwt for the Pecos River. Analysis of gizzard shad and white bass for the NCBP in 1984 from Red Bluff Reservoir indicated arsenic residues up to 0.29 ug/g wwt. A brown trout sample of liver/kidney tissue from Panchuela Creek campground had 0.08 ug/g wwt arsenic. These data compare to arsenic residues up to 0.082 ug/g wwt in rainbow trout liver 'at the Kendrick Reclamation Project in Wyoming (Peterson et al. 1988). Whole-body arsenic residues greater than 0.5 ug/g were reported by Walsh et al. (1977) to be harmful to fish and predators that fed on them. The data in this study indicate that localized arsenic contamination may exist at Jack's Creek campground; however, levels do not appear to be high enough to cause environmental concern.

<u>Cadmium</u>

Cadmium is a heavy metal that normally occurs in the earth's cruet in minute amounts. The occurrence of cadmium has been linked to gold and copper mines. Cadmium has also been noted by the NRC (1980) as occurring in zinc ores. The NMEID work plan indicated that a CERCLA report had identified cadmium as a potential on-site element. Cadmium is reported to produce anemia, bone demineralization, and kidney damage when ingested in moderate amounts. Cadmium is antagonistic to the effects of zinc and other essential elements.

Cadmium residues were detected in all liver/kidney samples of deer mice from campgrounds in the Terrero area. Deer mouse samples from the control site had no detectable cadmium residues. Maximum cadmium residues in mammal liver/kidney tissue occurred at Willow Creek campground (1.63 ug/g wwt), followed by Panchuela campground (1.31 ug/g wwt) and Jack's Creek (0.6 ug/g wwt). Reported residues may reflect runoff from Terrero Mine spoil piles or construction of campground facilities using mine tailings. A definitive statement regarding cadmium residues in mammals cannot be made due to different species being collected at the Willow Creek versus the other campgrounds; however, these data clearly indicated that cadmium is elevated in the areas influenced by mining activity.

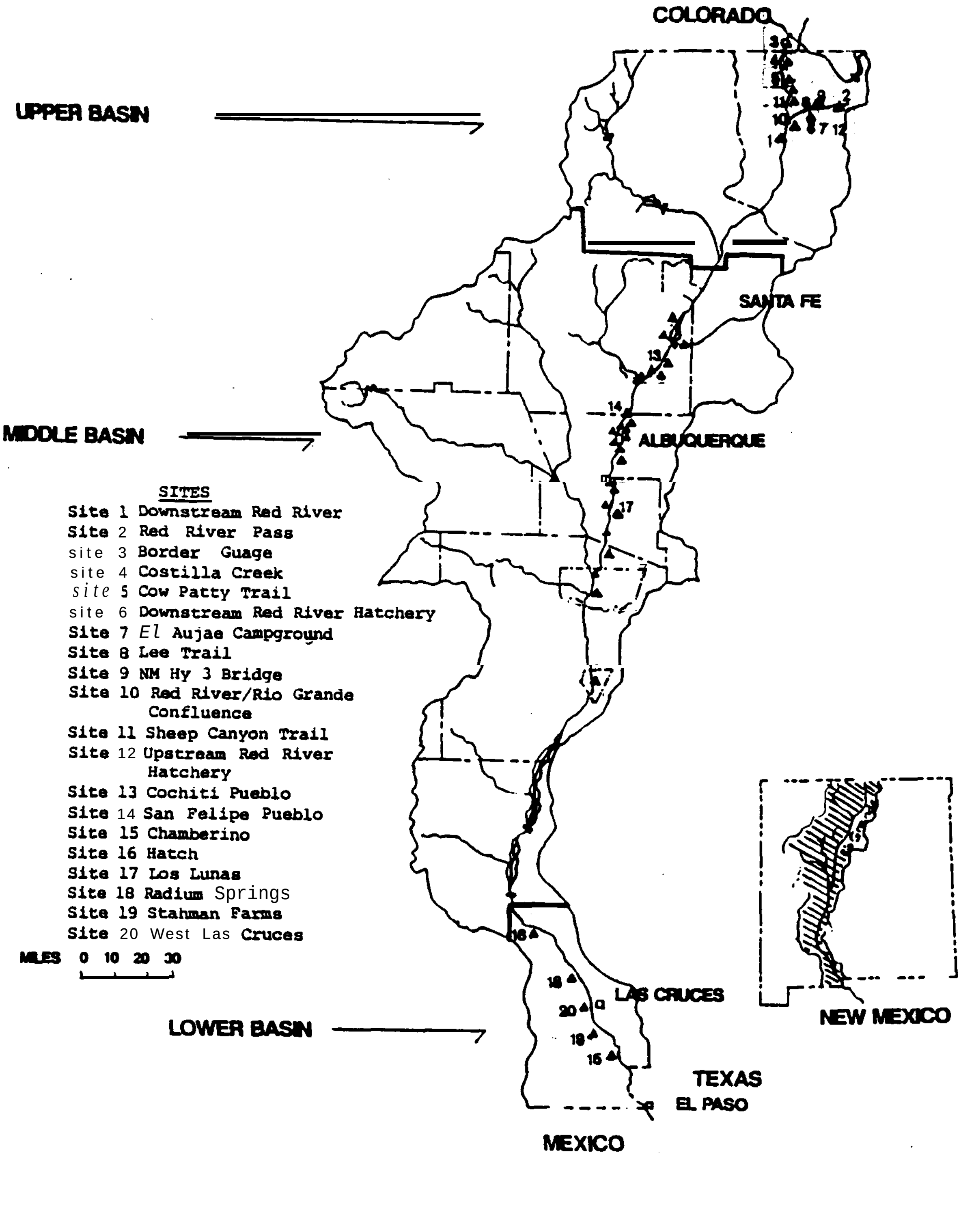
TABLE 3: TRACE ELEMENT RESIDUES IN BIOLOGICAL SAMPLES (ug/gram dry weight) COLLECTED FROM THE TERRERO MINE WASTE SITE AREA, 1990

COMMON NAME	MATRIX	SAMPLE TYPE	SAMPLE LOCATION	SAMPLE WT.(gms)	%MOIST	Al	b	Ba	Be	B	Cd	Co	Cr
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (4)	PANCH CAMP	10.20	72.9	<20.0	<20.0	<1.00	<0.20	<2.00	2.06	<3.0	<3.00
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (6)	PANCH CAMP	10.30	73.8	<20.0	<20.0	<1.00	<0.20	<2.00	1.63	<3.0	<3.00
LST CHIPMUNK	LIVER/KIDNEY	COMPOSITE (3)	JACK'S CREEK	10.00	75.6	<20.0	<20.0	<1.00	<0.20	<2.00	8.855	<3.0	<3.00
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (6)	JACK'S CREEK	10.10	72.6	<20.0	<20.0	<1.00	<0.20	<2.00	1.55	<3.0	<3.00
LST CHIPMUNK	LIVER/KIDNEY	COMPOSITE (3)	JACK'S CREEK	9.40	74.8	<20.0	<20.0	<1.00	<0.20	<2.00	<0.500	<3.0	<3.00
LST CHIPMUNK	LIVER/KIDNEY	INDIVIDUAL	JACK'S CREEK	2.90	75.6	<20.0	<20.0	<1.00	<0.20	3.20	<0.500	<3.0	<3.00
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	PANCH CAMP	13.20	75.2	<20.0	<20.0	<1.00	<0.20	<2.00	0.975	<3.0	<3.00
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	JACK'S CREEK	13.50	74.5	<20.0	<20.0	<1.00	<0.20	<2.00	0.718	<3.0	<3.00
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (6)	PANCH CAMP	10.00	73.2	<20.0	<20.0	<1.00	<0.20	<2.00	0.536	<3.0	<3.00
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (7)	PANCH CAMP	10.70	73.8	<20.0	<20.0	<1.00	<0.20	<2.00	1.20	<3.0	<3.00
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	PANCH CAMP	8.60	70.2	<20.0	<20.0	<1.00	<0.20	<2.00	4.41	<3.0	<3.00
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	JACK'S CREEK	10.40	69.5	<20.0	<20.0	<1.00	<0.20	<2.00	1.30	<3.0	<3.00
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	JACK'S CREEK	12.10	71.0	<20.0	<20.0	<1.00	0.42	<2.00	2.07	<3.0	<3.00
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (6)	JACK'S CREEK	10.20	73.4	<20.0	<20.0	<1.00	<0.20	<2.00	1.00	<3.0	<3.00
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (7)	JACK'S CREEK	10.10	74.0	<20.0	<20.0	<1.00	<0.20	<2.00	0.838	<3.0	<3.00
BRN TROUT	EDIBLE PORTION	COMPOSITE (18)	CAVE CREEK	UNK	76.7	<20.0	<20.0	1.22	<0.20	<2.00	<0.500	<3.0	<3.00
BRN TROUT	LIVER/KIDNEY	COMPOSITE (30)	CAVE CREEK	UNK	76.7	195.0	<20.0	2.17	<0.20	<2.00	1.54	<3.0	<3.00
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (5)	WILLOW CREEK	7.00	75.0	<20.0	<20.0	<1.00	<0.20	<2.00	1.02	<3.0	<3.00
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (6)	UPPER WILLOW	10.10	74.8	<20.0	<20.0	<1.00	<0.20	<2.00	<0.500	<3.0	<3.00
LST CHIPMUNK	LIVER/KIDNEY	COMPOSITE (2)	WILLOW CREEK	4.50	76.8	<20.0	<20.0	<1.00	<0.20	2.94	7.03	<3.0	<3.00
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	WILLOW CREEK	11.90	72.9	<20.0	<20.0	<1.00	<0.20	<2.00	<0.500	<3.0	<3.00
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (7)	UPPER WILLOW	10.90	74.5	<20.0	<20.0	<1.00	<0.20	2.09	<0.500	<3.0	<3.00
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	WILLOW CREEK	10.20	75.8	<20.0	<20.0	<1.00	<0.20	<2.00	<0.500	<3.0	<3.00
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	WILLOW CREEK	8.80	75.6	<20.0	<20.0	<1.00	<0.20	<2.00	<0.500	<3.0	<3.00
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (7)	UPPER WILLOW	8.10	74.6	<20.0	<20.0	<1.00	<0.20	<2.00	<0.500	<3.0	<3.00
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	WILLOW CREEK	10.40	74.8	<20.0	<20.0	<1.00	<0.20	<2.00	<0.500	<3.0	<3.00
RNB TROUT	WHOLE BODY	COMPOSITE (6)	ABOVE RIO MORA	546.00	73.7	48.9	<5.0	2.82	<0.10	0.51	<0.150	<0.5	1.10
RNB TROUT	FILLET	INDIVIDUAL	ABOVE RIO MORA	42.00	71.8	<3.0	<5.0	0.72	<0.10	<0.50	<0.150	<0.5	<0.50
RNB TROUT	FILLET	INDIVIDUAL	ABOVE RIO MORA	54.00	72.4	3.5	<5.0	0.50	<0.10	<0.50	<0.150	<0.5	<0.50
RNB TROUT	FILLET	INDIVIDUAL	ABOVE RIO MORA	39.00	73.0	<3.0	<5.0	<0.50	<0.10	0.57	<0.150	<0.5	<0.50
RNB TROUT	FILLET	INDIVIDUAL	ABOVE RIO MORA	36.00	75.1	<3.0	<5.0	0.50	<0.10	<0.50	<0.150	<0.5	<0.50
RNB TROUT	FILLET	INDIVIDUAL	ABOVE RIO MORA	36.00	74.6	38.6	<5.0	0.80	<0.10	<0.50	<0.150	<0.5	0.54
BRN TROUT	WHOLE BODY	COMPOSITE (5)	ABOVE LISBOA SP	363.00	75.9	212.0	<5.0	4.28	<0.10	<0.50	0.759	<0.5	1.29
BRN TROUT	FILLET	INDIVIDUAL	ABOVE LISBOA SP	27.00	74.0	<3.0	<5.0	1.11	<0.10	<0.50	0.170	<0.5	0.61
BRN TROUT	FILLET	INDIVIDUAL	ABOVE LISBOA SP	21.00	74.6	<3.0	<5.0	<0.50	<0.10	<0.50	0.183	<0.5	<0.50
BRN TROUT	FILLET	INDIVIDUAL	ABOVE LISBOA SP	15.00	73.5	<3.0	<5.0	0.68	<0.10	<0.50	<0.150	<0.5	<0.50
BRN TROUT	FILLET	INDIVIDUAL	ABOVE LISBOA SP	15.00	74.0	11.9	<5.0	1.43	<0.10	0.60	0.166	<0.5	<0.50
BRN TROUT	FILLET	INDIVIDUAL	ABOVE LISBOA SP	28.00	74.4	18.0	<5.0	0.94	<0.10	<0.50	<0.150	<0.5	<0.50

TABLE 3 CONTINUED: TRACE ELEMENT RESIDUES IN BIOLOGICAL SAMPLES (ug/gram dry weight) COLLBCTKD FROM THE TKRRKRO MINE WASTE SITE AREA, 1990

COMMON NAME	SAMPLE WT.(gms)	%MOIST	Cu	Fe	Pb	Mg	Mn	Mo	Ni	Ag	Sr	Sn	V	Zn	As	Hg	Se
DBER MOUSE	10.20	71.9	11.10	961.0	14.00	729	9.35	(5.0	<4.0	(5.0	<2.00	(10.0	(0.5	81.6	(0.30	0.118	5.66
DBER MOUSE	10.30	73.8	19.30	576.0	10.20	703	8.75	<5.0	<4.0	<5.0	<2.00	<20.0	<0.5	86.7	<0.30	<0.020	5.55
LST CHIPMUNK	10.00	75.6	25.30	862.0	<5.00	685	7.41	<5.0	<4.0	<5.0	<2.00	(10.0	<0.5	103.0	1.42	<0.020	1.44
DBER MOUSE	10.10	72.6	16.80	506.0	<5.00	731	8.11	(5.0	(4.0	(5.0	<2.00	<20.0	(0.5	85.7	(0.30	0.103	4.15
LST CHIPMUNK	9.40	74.8	19.70	1110.0	5.08	708	7.53	(5.0	<4.0	(5.0	(1.00	(10.0	(0.5	89.1	1.86	co.010	1.44
LST CHIPMUNK	2.90	75.6	24.40	764.0	(5.00	674	8.68	(5.0	<4.0	(5.0	<2.00	(10.0	(0.5	99.4	7.49	<0.020	1.45
GR SQRL	13.20	75.2	23.10	1010.0	(5.00	601	8.10	(5.0	(4.0	(5.0	<2.00	<20.0	(0.5	104.0	<0.30	0.056	3.07
GR SQRL	13.50	74.5	14.90	709.0	(5.00	615	7.56	(5.0	(4.0	(5.0	<2.00	<20.0	(0.5	91.0	<0.30	0.112	1.97
DKKR MOUSE	10.00	73.1	15.40	585.0	(5.00	673	6.93	(5.0	(4.0	(5.0	<2.00	<20.0	(0.5	85.8	(0.30	<0.020	4.40
DKKR HOUSK	10.70	73.8	13.10	615.0	(5.00	714	8.96	(5.0	(4.0	(5.0	<2.00	<20.0	(0.5	85.5	(0.30	<0.020	5.11
CR SQRL	8.60	70.1	21.50	161.0	(5.00	688	10.50	(5.0	(4.0	(5.0	(1.00	<20.0	(0.5	114.0	0.40	1.280	4.19
CR SQRL	10.40	69.5	19.30	418.0	(5.00	687	9.84	(5.0	<4.0	(5.0	<2.00	<20.0	<0.5	109.0	(0.30	0.335	3.19
GR SQRL	12.10	71.0	11.90	457.0	5.91	671	9.22	(5.0	(4.0	(5.0	(1.00	<20.0	0.6	103.0	(0.30	0.158	3.13
DBER MOUSE	10.20	73.4	15.80	640.0	(5.00	720	7.58	(5.0	<4.0	<5.0	<2.00	<20.0	(0.5	78.3	(0.30	(0.010	3.65
DBER MOUSE	10.10	74.0	17.40	598.0	(5.00	750	7.61	(5.0	<4.0	(5.0	<2.00	(10.0	(0.5	84.1	(0.30	(0.010	4.54
BRN TROUT	UNK	76.7	14.50	30.7	(5.00	1290	1.80	(5.0	<4.0	(5.0	19.40	<20.0	(0.5	95.6	0.58	0.137	3.81
BRN TROUT	UNK	76.7	196.00	514.0	6.36	766	4.86	(5.0	<4.0	(5.0	(1.00	<20.0	(0.5	97.8	0.33	0.177	18.40
DBER MOUSE	7.00	75.0	24.50	506.0	(5.00	808	5.01	(5.0	<4.0	(5.0	<2.00	<20.0	1.0	98.0	(0.30	<0.020	3.05
DBER MOUSE	10.10	74.8	27.40	631.0	(5.00	746	8.68	(5.0	<4.0	(5.0	(1.00	(10.0	<0.5	94.3	<0.30	0.160	3.85
LST CHIPMUNK	4.50	76.8	25.30	1090.0	(5.00	776	5.91	(5.0	<4.0	(5.0	<2.00	<20.0	<0.5	114.0	0.66	(0.010	3.10
GR SQRL	11.90	71.9	24.00	1010.0	(5.00	580	5.56	(5.0	<4.0	(5.0	<2.00	<20.0	<0.5	81.7	(0.30	(0.010	1.69
DKKR MOUSE	10.90	74.5	15.60	479.0	(5.00	711	7.19	(5.0	<4.0	(5.0	<2.00	<20.0	(0.5	99.7	<0.30	<0.020	4.05
GR SQRL	10.10	75.8	16.70	468.0	(5.00	748	6.40	(5.0	<4.0	(5.0	(1.00	<20.0	(0.5	101.0	(0.30	<0.020	1.53
GR SQRL	8.80	75.6	24.50	631.0	(5.00	711	10.9	(5.0	<4.0	(5.0	<2.00	<20.0	(0.5	133.0	(0.30	<0.020	1.31
DBER MOUSE	8.10	74.6	18.10	477.0	(5.00	744	6.56	(5.0	(4.0	(5.0	(1.00	(10.0	(0.5	84.0	(0.30	0.115	1.98
GR SQRL	10.40	74.8	17.00	741.0	(5.00	663	6.47	(5.0	(4.0	<5.0	<2.00	(10.0	(0.5	92.7	<0.30	<0.020	2.04
RNB TROUT	546.00	73.7	5.51	166.0	5.78	1370	10.20	<0.8	<0.8	(1.5	32.20	< 5.0	(0.5	101.0	0.53	0.020	1.69
RNB TROUT	41.00	71.8	1.41	31.1	<0.20	1210	1.07	(0.8	(0.8	(1.5	6.76	< 5.0	(0.5	31.0	0.99	(0.010	1.41
RNB TROUT	54.00	71.4	1.58	16.6	(0.10	1320	2.37	(0.8	(0.8	(1.5	3.61	< 5.0	<0.5	19.0	1.08	0.098	1.13
RNB TROUT	39.00	73.0	1.51	17.1	<0.20	1120	0.93	<0.8	<0.8	(1.5	1.13	< 5.0	(0.5	20.3	0.72	(0.010	1.33
RNB TROUT	36.00	75.1	1.58	23.0	<0.20	1230	1.81	<0.8	<0.8	(1.5	4.96	< 5.0	(0.5	38.3	0.57	0.041	1.18
RNB TROUT	36.00	74.6	2.13	80.8	0.45	1310	3.00	<0.8	<0.8	(1.5	3.68	< 5.0	(0.5	19.9	0.75	0.071	1.34
BRN TROUT	363.00	75.9	10.00	304.0	2.30	1440	16.40	(0.8	<0.8	(1.5	35.70	< 5.0	(0.5	185.0	0.34	0.151	5.86
BRN TROUT	27.00	74.0	2.31	26.7	0.38	1390	3.88	(0.8	<0.8	(1.5	11.30	< 5.0	(0.5	80.3	(0.30	0.185	4.26
BRN TROUT	21.00	74.6	1.87	19.3	0.48	1070	1.44	(0.8	<0.8	(1.5	4.36	< 5.0	(0.5	50.0	0.81	0.160	5.58
BRN TROUT	15.00	73.5	1.16	22.6	<0.20	1000	2.04	(0.8	(0.8	(1.5	4.83	< 5.0	(0.5	44.1	(0.30	0.102	3.56
BRR TROUT	15.00	74.0	<0.50	15.3	0.54	1340	4.65	(0.8	(0.8	(1.5	9.74	< 5.0	(0.5	73.2	0.56	0.079	4.77
BRN TROUT	18.00	74.4	<0.50	71.31	1.06	1070	4.04	(0.8	(0.8	(1.5	7.91	< 5.0	(0.5	75.4	0.94	0.151	4.74

FIGURE 2: Sample collection locations of fish and birds in the Rio Grande Basin in New Mexico, 1985–87.



RIO GRANDE BASIN

TABLE 4: TRACE ELEMENT RESIDUES IN BIOLOGICAL SAMPLES (ug/gram dry weight) COLLECTED FROM LOCATIONS □ THE RIO GRANDE FROM 1985-87. (ROY AND O'BRIEN 1991)

COMMON NAME		LOCATION	Al(dry)	Sb(dry)	As(dry)	Ba(dry)	Be(dry)	B(dry)	Cd(dry)	Cr(dry)	Cu(dry)	Fe(dry)	Pb(dry)	Mg(dry)
BROOK TROUT	1	DOWNSTREAM RED RIVER	97.3	ND	1.16	2.90	ND	ND	0.43	ND	13.30	254.0	ND	1170.0
BROOK TROUT	2	RED RIVER PASS	55.0	ND	1.08	4.50	ND	ND	ND	ND	3.49	161.0	ND	1310.0
BROWN TROUT	3	BORDER GAUGE	17.0		0.20	0.59	<0.10	<2.00	<0.30	<1.00	18.00	78.0	<4.00	1040.0
BROWN TROUT	4	COSTILLA CREEK	15.0		0.20	1.10	<0.10	<2.00	<0.30	2.00	3.30	86.0	<4.00	1070.0
BROWN TROUT	4	COSTILLA CREEK	<3.00		<0.10	0.57	<0.10	<2.00	<0.30	<1.00	3.30	53.0	<4.00	1050.0
BROWN TROUT	5	COW PATTY	37.0		0.20	1.00	<0.10	<2.00	<0.20	1.00	11.00	93.0	<4.00	988.0
BROWN TROUT	6	DOWNSTREAM RED RIVER HATCHERY	33.9	ND	1.38	ND	ND	ND	0.31	ND	8.44	53.8	5.14	707.0
BROWN TROUT	6	DOWNSTREAM RED RIVER HATCHERY	24.2	ND	0.87	ND	ND	ND	1.01	ND	9.88	57.2	5.14	919.0
BROWN TROUT	6	DOWNSTREAM RED RIVER HATCHERY	ND	ND	1.76	ND	ND	ND	0.36	ND	9.03	45.4	1.23	735.0
BROWN TROUT	7	EL AUJAE CAMPGROUND	8.3	ND	0.84	ND	ND	ND	0.62	ND	12.70	89.1	1.68	898.0
BROWN TROUT	7	EL AUJAE CAMPGROUND	64.8	ND	0.63	3.60	ND	ND	1.16	ND	8.14	148.0	1.40	1250.0
BROWN TROUT	8	LEE TRAIL	9.6		<0.10	0.53	<0.10	<2.00	<0.30	1.00	7.00	66.0	<4.00	965.0
BROWN TROUT	9	NM HWY 3 BRIDGE	117.0	ND	0.55	ND	ND	ND	0.63	ND	16.10	148.0	ND	1000.0
BROWN TROUT	10	RED RIVER/RIO GRANDE CONFLUENCE	170.0		0.20	3.00	<0.10	<2.00	0.60	1.00	6.40	230.0	<4.00	1220.0
BROWN TROUT	11	SHEEP CANYON	34.0		<0.10	1.10	<0.10	<2.00	<0.20	1.00	7.60	113.0	<4.00	951.0
BROWN TROUT	12	UPSTREAM RED RIVER HATCHERY DIV.	70.3	ND	0.43	2.10	ND	ND	0.98	ND	14.10	123.0	ND	985.0
BROWN TROUT	12	UPSTREAM RED RIVER HATCHERY DIV.	47.2	ND	2.95	ND	ND	ND	ND	ND	9.40	61.4	ND	882.0
RAINBOW TROUT	13	COCHITI PUEBLO	ND	ND	ND	2.30	ND	ND	ND	ND	4.76	158.0	ND	1090.0
RAINBOW TROUT	1	DOWNSTREAM RED RIVER	36.6	ND	1.29	1.90	ND	ND	ND	ND	6.85	116.0	ND	1030.0
RAINBOW TROUT	2	RED RIVER PASS	9.8	ND	ND	2.10	ND	ND	ND	ND	6.21	95.8	ND	1220.0
RAINBOW TROUT	10	RED RIVER/RIO GRANDE CONFLUENCE	660.0		0.72	9.50	<0.10	<2.00	<0.20	2.00	6.70	719.0	<4.00	1380.0
RAINBOW TROUT	14	RIO GRANDE AT SAN FELIPE PUEBLO	40.5	ND	ND	4.70	ND	ND	0.49	ND	7.78	151.0	ND	997.0
RAINBOW TROUT	14	RIO GRANDE AT SAN FELIPE PUEBLO	9.1	ND	ND	6.21	ND	ND	ND	ND	5.41	106.0	ND	1170.0
RAINBOW TROUT	11	SHEEP CANYON	200.0		0.20	5.70	<0.10	<2.00	<0.30	1.00	3.40	499.0	<5.00	1230.0
RG CUTTHROAT	2	RED RIVER PASS	32.1	ND	1.11	3.00	ND	ND	ND	ND	5.69	206.0	ND	1190.0
MICE	15	CHAMBERINO	3.4		0.25		0.034		0.18	<0.24	16.62	486.2	1.23	676.9
MICE	16	HATCH	7.7		0.15		0.033		0.12	<0.24	18.18	464.3	0.89	833.3
MICE	17	LOS LUNAS	8.0		0.28		0.037		0.30	<0.27	18.04	513.8	1.87	795.1
MICE	18	RADIUM SPRINGS	7.2		0.31		0.030		1.03	<0.25	14.64	529.6	<0.63	810.0
MICE	19	STAHMAN FARMS	5.0		<0.16		0.031		0.09	<0.25	15.63	475.0	0.63	781.3
MICE	20	WEST LAS CRUCES	6.2		<0.15		0.037		0.15	<0.27	17.23	452.3	0.62	861.5

TABLE 4 CONTINUED: TRACE ELEMENT RESIDUES IN BIOLOGICAL SAMPLES (ug/gram dry weight) COLLECTED FROM LOCATIONS IN THE RIO GRANDE FROM 1985-87. (ROY AND O'BRIEN 1991)

COMMON NAME		LOCATION	Mn(dry)	Hg(dry)	Mo(dry)	Ni(dry)	Se(dry)	Ag(dry)	Sr(dry)	Tl(dry)	Sn(dry)	V(dry)	Zn(dry)
BROOK TROUT	1	DOWNSTREAM RED RIVER	10.00	0.04	ND	ND	1.79	ND	48.10	ND	28.30	ND	98.30
BROOK TROUT	2	RED RIVER PASS	15.40	0.10	ND	3.34	3.55	ND	76.30	ND	26.00	ND	93.20
BROWN TROUT	3	BORDER GAUGE	3.5	0.77	<1.00	<2.00	2.70	<2.00	21.70	<4.00		<0.300	131.00
BROWN TROUT	4	COSTILLA CREEK	7.0	0.37	<1.00	<1.00	1.60	<2.00	44.90	<5.00		0.30	108.00
BROWN TROUT	4	COSTILLA CREEK	5.4	0.49	<1.00	<1.00	2.40	<2.00	27.70	<5.00		0.30	106.00
BROWN TROUT	5	COW PATTY	6.2	0.68	<1.00	<1.00	2.40	<2.00	30.30	<5.00		0.30	119.00
BROWN TROUT	6	DOWNSTREAM RED RIVER HATCHERY	2.42	0.12	ND	ND	1.63	ND	27.80	ND	60.40	ND	83.70
BROWN TROUT	6	DOWNSTREAM RED RIVER HATCHERY	31.20	0.02	ND	4.86	2.42	ND	35.50	ND	38.30	ND	155.00
BROWN TROUT	6	DOWNSTREAM RED RIVER HATCHERY	5.92	0.07	ND	ND	1.45	ND	32.80	ND	52.50	ND	71.50
BROWN TROUT	7	EL AUJAE CAMPGROUND	60.80	0.04	ND	ND	2.71	ND	40.40	ND	25.50	ND	130.00
BROWN TROUT	7	EL AUJAE CAMPGROUND	65.90	0.03	ND	6.15	2.20	ND	79.30	ND	78.00	ND	267.00
BROWN TROUT	8	LEE TRAIL	3.9	0.71	<1.00	2.00	2.00	<2.00	22.30	<5.00		0.50	98.40
BROWN TROUT	9	NM HWY 3 BRIDGE	14.40	0.04	ND	1.36	2.24	ND	31.60	ND	70.30	ND	142.00
BROWN TROUT	10	RED RIVER/RIO GRANDE CONFLUENCE	80.2	0.03	<1.00	2.00	1.80	<2.00	32.80	<5.00		0.70	173.00
BROWN TROUT	11	SHEEP CANYON	10.0	0.41	<1.00	<1.00	2.20	<2.00	19.50	<5.00		0.40	110.00
BROWN TROUT	12	UPSTREAM RED RIVER HATCHERY DIV.	26.10	0.04	ND	1.13	2.02	ND	37.40	ND	32.50	ND	219.00
BROWN TROUT	12	UPSTREAM RED RIVER HATCHERY DIV.	3.69	0.22	ND	2.33	1.93	ND	48.80	ND	26.50	ND	99.30
RAINBOW TROUT	13	COCHITI PUEBLO	7.79	0.29	ND	ND	1.62	ND	48.30	ND	81.20	ND	95.10
RAINBOW TROUT	1	DOWNSTREAM RED RIVER	10.40	0.05	ND	1.79	0.74	ND	66.50	ND	26.00	ND	84.80
RAINBOW TROUT	2	RED RIVER PASS	5.33	0.07	ND	ND	0.81	ND	98.60	ND	78.40	ND	128.00
RAINBOW TROUT	10	RED RIVER/RIO GRANDE CONFLUENCE	146.0	0.07	<1.00	3.00	1.50	<2.00	32.90	<5.00		1.50	142.00
RAINBOW TROUT	14	RIO GRANDE AT SAN FELIPE PUEBLO	10.90	0.03	ND	ND	1.67	ND	67.70	ND	ND	ND	130.00
RAINBOW TROUT	14	RIO GRANDE AT SAN FELIPE PUEBLO	13.10	0.09	ND	ND	1.59	ND	83.10	ND	ND	ND	101.00
RAINBOW TROUT	11	SHEEP CANYON	53.6	0.12	<1.00	<1.00	1.40	<2.00	36.90	<5.00		1.30	96.10
RG CUTTHROAT	2	RED RIVER PASS	11.80	0.09	ND	ND	5.49	ND	33.40	ND	ND	ND	81.40
MICE	15	CHAMBERINO	6.00	<0.06	7.08	1.05	1.91			<2.42			71.08
MICE	16	HATCH	6.93	<0.06	5.95	0.60	2.29			<2.35			76.19
MICE	17	LOS LUNAS	7.52	0.09	7.03	0.61	4.28			<2.73			73.70
MICE	18	RADIUM SPRINGS	6.07	<0.06	4.05	0.62	4.67			<2.50			75.08
MICE	19	STAHMAN FARMS	5.06	<0.06	5.94	0.63	2.47			<2.5			74.38
MICE	20	WEST LAS CRUCES	7.02	<0.06	4.92	1.08	4.00			<2.73			78.15

Table 5. Ranges of Trace Elements in Biological Samples from the Terrero Mine Vicinity Compared to Similar Samples from the Rio Grande and Geochemical Baseline Values (ug/g [ppm] Dry Weight).

	>10% elevated"	Terrero Pecos Ri. Geometric mean/ range	Rio Grande Geometric mean/ range	Geo Chemical baseline Geometric mean/range"
Aluminum		16.4/3.0-212	25.0/3.0-660	58,000/15,000-230,000
Antimony		-/<5.0	ND"	ND[3/]
Barium		1.0/<0.5-4.28	2.18/053-9.5	580/200-1,700
Beryllium		0.16/<0.10-0.42	0.033/0.03-0.037	0.68/0.13-3.6
Boron		1.33/<0.5-3.2	-/<2.0	23/5.8-91
Cadmium	*	0.557/<0.15-7.03	0.35/0.09-1.16	/.020-0.182
Cobalt		-/<0.5	NA[4/]	7.1/1.8-28
Chromium		0.82/<0.5-1.29	0.63/<0.24-3.0	41/8.5-200
Copper	*	9.95/<0.5-196	8.7/3.3-18.18	21/4.9-90
Iron		249/17.1-1,110	157.5/45.4-719	21,000/5,500-80,000
Lead	*	2.54/<0.2-14.0	2.26/0.62-5.14	17/5.2-55
Magnesium		853/580-1,440	990/677-1,380	7,400/1,500-36,000
Manganese		5.59/0.93-16.4	11.24/2.42-146	380/97-1,500
Molybdenum		-/<0.8	2.01/<1.0-7.08	0.85/0.18-4.0
Nickel		-/<0.8	1.43/0.53-6.15	15/3.4-66
Silver		-/<1.5	-/<2.0	ND[3/]
Strontium		3.2/<2.0-35.7	40.8/19.5-98.6	200/49-930
Tin		-/<5.0	43.12/25.5-81.2	ND[3/]
Vanadium		-/<0.5-1.0	0.51/0.30-1.5	70/18-270
Zinc	*	78.7/20.3-185	106.9/71.1-267	55/17-180
Arsenic	*	0.47/<0.3-7.49	0.4/0.1-2.95	5.5/1.2-22
Mercury	*	0.056/<0.02-1.28	0.1/0.02-0.77	0.046/0.0085-0.25
Selenium	*	3.17/1.18-28.4	2.1/0.74-5.49	0.23/0.039-1.4

[1/] Elevated by >10 percent over Rio Grande or baseline data.
[2/] Shacklette and Boerngen (1984).
[3/] No data available
[4/] Not analyzed

TABLE 6: TRACE ELEMENT RESIDUES IN BIOLOGICAL SAMPLES (ug/gram wet weight) COLLECTED FROM THE TERRERO MINE WASTE AREA, 1990

COMMON NAME	MATRIX	SAMPLE TYPE	SAMPLE LOCATION	Cd	Cu	Pb	Zn	As	Hg	Se
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (4)	PANCH CAMP	0.56	6.02	3.79	22.38	<0.08	0.03	1.53
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (6)	PANCH CAMP	0.43	5.06	2.67	22.72	<0.08	<0.01	1.45
LST CHIPMUNK	LIVER/KIDNEY	COMPOSITE (3)	JACK'S CREEK	0.21	6.17	< 1.22	25.13	0.35	<0.00	0.60
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (6)	JACK'S CREEK	0.42	4.60	< 1.37	23.48	<0.08	0.03	1.14
LST CHIPMUNK	LIVER/KIDNEY	COMPOSITE (3)	JACK'S CREEK	<0.13	4.96	1.28	22.45	0.47	<0.01	0.61
LST CHIPMUNK	LIVER/KIDNEY	INDIVIDUAL	JACK'S CREEK	<0.12	5.95	< 1.22	24.25	1.83	<0.01	0.60
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	PANCH CAMP	0.24	5.73	< 1.24	25.79	<0.07	0.01	0.76
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	JACK'S CREEK	0.18	3.80	< 1.28	23.21	<0.08	0.03	0.76
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (6)	PANCH CAMP	0.14	4.13	< 1.34	22.99	<0.08	<0.01	1.18
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (7)	PANCH CAMP	0.31	6.08	< 1.31	22.40	<0.08	<0.01	1.34
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	PANCH CAMP	1.31	6.41	< 1.49	33.97	0.12	0.38	1.25
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	JACK'S CREEK	0.40	5.89	< 1.53	33.25	<0.09	0.10	1.00
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	JACK'S CREEK	0.60	6.64	1.72	29.87	<0.09	0.07	0.94
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (6)	JACK'S CREEK	0.27	4.20	< 1.33	20.83	<0.08	<0.01	0.97
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (7)	JACK'S CREEK	0.22	4.52	< 1.30	21.89	<0.08	<0.01	1.18
BRN TROUT	EDIBLE PORTION	COMPOSITE (18)	CAVE CREEK	<0.12	3.38	< 1.16	22.27	0.13	0.06	0.89
BRN TROUT	LIVER/KIDNEY	COMPOSITE (30)	CAVE CREEK	0.36	45.67	1.48	22.79	0.08	0.04	6.62
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (5)	WILLOW CREEK	0.26	6.13	< 1.25	24.50	<0.08	<0.01	0.76
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (6)	UPPER WILLOW	<0.13	6.90	< 1.26	23.76	<0.08	0.04	0.97
LST CHIPMUNK	LIVER/KIDNEY	COMPOSITE (2)	WILLOW CREEK	1.63	5.87	< 1.16	26.45	0.15	<0.01	0.74
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	WILLOW CREEK	<0.14	6.50	< 1.35	22.41	<0.08	<0.01	0.46
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (7)	UPPER WILLOW	<0.13	6.53	< 1.28	25.42	<0.08	<0.01	1.03
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	WILLOW CREEK	<0.12	4.04	< 1.21	24.44	<0.07	<0.01	0.61
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	WILLOW CREEK	<0.12	5.98	< 1.22	32.45	<0.07	<0.01	0.32
DEER MOUSE	LIVER/KIDNEY	COMPOSITE (7)	UPPER WILLOW	<0.13	4.62	< 1.27	21.34	<0.08	0.03	0.76
GR SQRL	LIVER/KIDNEY	INDIVIDUAL	WILLOW CREEK	<0.13	4.28	< 1.26	23.36	<0.08	<0.01	0.51
RNB TROUT	WHOLE BODY	COMPOSITE (6)	ABOVE RIO MORA	<0.04	1.45	1.45	26.60	0.14	0.005	0.44
RNB TROUT	FILLET	INDIVIDUAL	ABOVE RIO MORA	<0.04	0.40	< 0.05	9.02	0.28	<0.005	0.40
RNB TROUT	FILLET	INDIVIDUAL	ABOVE RIO MORA	<0.04	0.44	< 0.05	8.00	0.30	0.03	0.34
RNB TROUT	FILLET	INDIVIDUAL	ABOVE RIO MORA	<0.04	0.40	< 0.05	5.48	0.19	<0.005	0.35
RNB TROUT	FILLET	INDIVIDUAL	ABOVE RIO MORA	<0.04	0.39	< 0.05	9.54	0.14	0.01	0.29
RNB TROUT	FILLET	INDIVIDUAL	ABOVE RIO MORA	<0.04	0.54	0.11	7.59	0.19	0.02	0.34
BRN TROUT	WHOLE BODY	COMPOSITE (5)	ABOVE LISBOA SP.	0.18	2.41	0.55	44.60	0.08	0.04	1.41
BRN TROUT	FILLET	INDIVIDUAL	ABOVE LISBOA SP.	0.04	0.60	0.10	20.88	<0.08	0.05	1.11
BRN TROUT	FILLET	INDIVIDUAL	ABOVE LISBOA SP.	0.04	0.48	0.12	12.70	0.21	0.04	1.41
BRN TROUT	FILLET	INDIVIDUAL	ABOVE LISBOA SP.	<0.04	0.31	< 0.05	11.70	<0.08	0.03	0.94
BRN TROUT	FILLET	INDIVIDUAL	ABOVE LISBOA SP.	0.04	<0.13	0.14	19.03	0.14	0.02	1.24
BRN TROUT	FILLET	INDIVIDUAL	ABOVE LISBOA SP.	<0.04	<0.13	0.27	19.30	0.24	0.04	1.21

TABLE 7: **TRACE ELEMENT RESIDUES IN BIOLOGICAL SAMPLES (ug/gram wet weight) COLLECTED AT LOCATIONS IN THE RIO GRANDE FROM** 1985-87 (ROY AND **O'BRIEN** 1991)

COMMON NAME	LOCATION	As(wet)	Cd(wet)	Cu(wet)	Pb(wet)	Hg(wet)	Se(wet)	Zn(wet)
BROOK TROUT	DOWNSTREAM RED RIVER	0.29	0.11	3.31	ND	0.01	0.45	24.48
BROOK TROUT	RED RIVER PASS	0.28	ND	0.90	ND	0.03	0.92	24.05
BROWN TROUT	BORDER GAUGE	0.05	C0.08	4.72	<1.04	0.20	0.71	34.32
BROWN TROUT	COSTILLA CREEK	0.06	<0.09	1.01	<1.24	0.11	0.49	33.05
BROWN TROUT	COSTILLA CREEK	<0.03	<0.09	0.96	(1.16	0.14	0.70	30.85
BROWN TROUT	COW PATTY	0.05	<0.05	3.01	<1.08	0.19	0.66	32.61
BROWN TROUT	DOWNSTREAM RED RIVER HATCHERY	0.44	0.10	2.71	1.65	0.04	0.52	26.87
BROWN TROUT	DOWNSTREAM RED RIVER HATCHERY	0.23	0.27	2.61	1.36	0.01	0.64	40.92
BROWN TROUT	DOWNSTREAM RED RIVER HATCHERY	0.53	0.11	2.72	0.37	0.02	0.44	21.52
BROWN TROUT	EL AUJAE CAMPGROUND	0.21	0.16	3.26	0.43	0.01	0.70	33.41
BROWN TROUT	EL AUJAE CAMPGROUND	0.12	0.23	1.59	0.27	0.01	0.43	52.07
BROWN TROUT	LEE TRAIL	<0.03	(0.08	1.96	<1.12	0.20	0.56	27.55
BROWN TROUT	NM HWY 3 BRIDGE	0.16	0.18	4.62	ND	0.01	0.64	40.75
BROWN TROUT	RED RIVER/RIO GRANDE CONFLUENCE	0.05	0.15	1.61	<1.00	0.01	0.45	43.60
BROWN TROUT	SHEEP CANYON	(0.03	<0.05	2.04	<1.08	0.ll	0.59	29.59
BROWN TROUT	UPSTREAM RED RIVER HATCHERY DIV.	0.12	0.28	3.98	ND	0.01	0.57	61.76
BROWN TROUT	UPSTREAM RED RIVER HATCHERY DIV.	0.75	ND	2.39	ND	0.06	0.49	25.22
RAINBOW TROUT	COCHITI PUEBLO	ND	No	1.19	ND	0.07	0.41	23.87
RAINBOW TROUT	DOWNSTREAM RED RIVER	0.47	ND	2.50	ND	0.02	0.27	30.95
RAINBOW TROUT	RED RIVER PASS	No	ND	1.63	ND	0.02	0.21	33.54
RAINBOW TROUT	RED RIVER/RIO GRANDE CONFLUENCE	0.16	(0.04	1.47	C0.88	0.02	0.33	31.24
RAINBOW TROUT	RIO GRANDE AT SAN FELIPE PUEBLO	ND	0.15	2.35	ND	0.01	0.50	39.26
RAINBOW TROUT	RIO GRANDE AT SAN FELIPE PUEBLO	ND	ND	1.30	ND	0.02	0.38	24.34
RAINBOW TROUT	SHEEP CANYON	0.05	<0.08	0.87	a.30	0.03	0.36	24.70
RG CUTTHROAT	RED RIVER PASS	0.26	ND	1.32	ND	0.02	1.27	18.88
MICE	CHAMBERINO	0.08	0.06	5.40	0.40	<0.02	0.62	23.10
MICE	HATCH	0.05	0.04	6.11	0.30	co.02	0.77	25.60
MICE	LOS LUNAS	0.09	0.10	5.90	0.61	0.03	1.40	24.10
MICE	RADIUM SPRINGS	0.10	0.33	4.70	<0.20	(0.02	1.50	24.10
MICE	STAHMAN FARMS	<0.05	0.03	5.00	0.20	<0.02	0.79	23.80
MICE	WEST LAS CRUCES	(0.05	0.05	5.60	0.20	<0.02	1.30	25.40

Table 8. Baseline Concentrations of Trace Elements in Fish (Concentrations in ug/g wet weight), from Schmitt and Brumbaugh 1990.

Element and Collection Period	Geometric Mean	Minimum	85th Percentile	Maximum
Lead				
1978-79	0.19	0.10	0.32	6.73
1980-81	0.17	0.10	0.25	1.94
1984-85	0.11	0.01	0.22	4.88
Mercury				
1978-79	0.11	0.01	0.18	1.10
1980-81	0.03	0.01	0.06	0.35
1984-85	0.10	0.01	0.17	0.37
Cadmium				
1978-79	0.04	0.01	0.09	0.41
1980-81	0.03	0.01	0.06	0.35
1984-85	0.03	0.01	0.05	0.22
Arsenic				
1978-79	0.16	0.04	0.23	2.08
1980-81	0.14	0.05	0.22	1.69
1984-85	0.14	0.02	0.27	1.50
Selenium				
1978-79	0.46	0.09	0.70	3.65
1980-81	0.47	0.09	0.71	2.47
1984-85	0.42	0.08	0.73	2.30
Copper				
1978-79	0.86	0.29	1.14	38.75
1980-81	0.68	0.25	0.90	24.10
1984-85	0.65	0.06	1.00	23.10
Zinc				
1978-79	25.63	7.69	46.26	168.10
1980-81	23.82	8.82	40.09	109.21
1984-85	21.70	9.60	34.20	118.40

Data from liver and kidney residue analyses have not been correlated with residues in muscle tissue; however, whole-body analysis normally results in lower residues of inorganic compounds, particularly those that are not lipid soluble. Beyer et al. (1985) reported on metal residues in several species of mammals exposed to metal contamination from a zinc smelter in Pennsylvania. Cadmium residues downwind from the smelter were reported to be as high as 710 ug/g dwt in soil. Corresponding analysis of white-footed mice indicated cadmium residues less than 1 ug/g wwt in livers and less than 5 ug/g wwt in kidney. The authors indicated species that decompose organic matter in soil and their predators are most likely to bioaccumulate cadmium. Rodents, therefore, may not be the best organism to use in this type of study. Eisler (1985b) reported that meadow voles from a study conducted to evaluate sewage sludge had cadmium residues in livers ranging from 0.8 to 3.1 ug/g wwt and residues in kidneys from 3.5 to 19.1 ug/g wwt. At a control field, meadow voles had residues in liver from 0.1 to' 0.7 ug/g wwt and residues in kidney from 0.3 to 1.1 ug/g wwt (Maly and Barrett 1984). Cadmium residues in liver and kidney tissue in all species from the Terrero area are generally within the range of values recorded at the control site by Maly and Barrett. The geometric mean of all mammal samples (using one-half of the detection limit for samples with no detectable residues) was 0.17 ug/g wwt, which is less than the data reported in literature.

Rainbow and brown trout samples from the upper Pecos River exhibited cadmium levels up to 0.759 ug/g dwt (0.36 ug/g wwt). Residue levels were lowest at the two sites above the Rio Mora (less than 0.04 ug/g wwt), while the highest value in a whole-body composite was detected above Lisboa Springs Hatchery (0.18 ug/g wwt). The highest cadmium level in brown trout (0.36 ug/g wwt) was found in a composite liver and kidney from Cave Creek. This is more likely to reflect the function of the kidney in waste excretion rather than the probable exposure level at Cave Creek (Goyer 1986). From the Rio Grande, the highest detected cadmium residue was 0.28 ug/g wwt in a brown trout whole-body composite sample (Table 7). Higher trace element residues in brown trout may reflect a higher piscivorous trophic level than the rainbow trout.

Schmitt and Brumbaugh (1990) reported the results of the 1984-85 NCBP from a total of 319 composite samples of fish from across the United States. The geometric mean whole-body concentration of cadmium in all fish from the NCBP was 0.03 ug/g wwt, with a range from 0.01 to 0.22 ug/g. The highest reported cadmium residue in either whole-body or edible portion fillet from the Pecos River of 0.18 ug/g wwt is below the maximum value of all fish from the NCBP (Table 8). Eisler (1985b) reported results of less than 0.05 ug/g wwt from a study of cadmium residues in whole-body rainbow trout from Arizona. Eisler indicated that cadmium residues of in excess 10 ug/g wwt in vertebrate kidney or 2 ug/g wwt in whole-body should be viewed as evidence of cadmium contamination. These sources suggest that cadmium residues from the Terrero Mine campgrounds or in the Pecos River do not represent an environmental hazard.

Copper

Copper is an essential element for metabolism and plays a key role in biological systems in hemoglobin formation. Normal copper residues in domestic mammal livers are reported to range from 15 to 30 ug/g dwt (NRC 1980). Residues of copper up to 27.4 ug/g dwt were found in mammal liver/kidney samples from the Terrero area. Maximum liver and kidney copper residues in mice from the Rio Grande study site were 18.18 ug/g dwt. Copper residues were lower in mammal tissue from Jack's Creek and Panchuela campgrounds than those at the control site.

Beyer et al. (1985) reported mean copper residues in carcasses of white-footed mice of 2.3 ug/g dwt and 6.7 ug/g dwt from two sites near a zinc smelter. They reported that analysis of carcass tissue versus carcass and internal organs produced similar residue results. Studies that report results of liver and kidney analysis are lacking, although it is normal to observe high metal residues in mammal liver and kidney tissue.

Fish from the Pecos River had maximum copper residue levels of 0.6 ug/g wwt in edible portion and 3.38 ug/g wwt in whole-body. A sample of brown trout liver and kidney tissue had copper residues of 45.67 ug/g wwt. There does not appear to be any gradient associated with copper residues from samples collected above Terrero Mine and those collected below the mine. In whole-body composite trout samples from the Rio Grande, copper values of 0.87 to 4.72 ug/g wwt were reported (Table 7). Data from the NCBP in 1984 for all fish in the United States indicated a range of copper in whole-body from 0.06 to 23.1 ug/g wwt. The NCBP geometric mean for copper was 0.65 ug/g wwt and the 85th percentile was 1.0 ug/g wwt. The average value of 1.93 ug/g wwt for copper residues in whole-body fish from the Pecos River is above the NCBP 85th percentile value. There are no predator protection limits for copper; however, some countries have placed a legal limit in fish and fishery products for consumption of 10 ug/g wwt (Irwin 1990). A screening site investigation of the Terrero Mine and some of the water seeps indicated elevated copper residues in water samples (Sinclair 1990). Elevated copper residues in some water samples may correlate with the apparent elevated copper residues in fish tissue. Copper residues do not appear to be high enough to warrant environmental concern.

Lead

At the Terrero Mine and the campgrounds along the Pecos River, lead has been identified as an environmental concern, particularly because lead was mined at the site. The NRC (1980) reported that lead occurs most often in the environment as lead sulfate ($PbSO_4$) which is more soluble in organic media. Lead residues in mammal tissue (liver and kidney) in the Terrero area were detected up to 3.79 ug/g wwt (14.0 ug/g dwt). The detection limits used by RTI for lead in mammal tissue in this study were not sensitive enough to adequately assess exposure in the small mammals. Residues of lead were detected in small mammals at Panchuela and Jack's Creek campgrounds. Deer mouse tissue exhibited elevated lead residues at Panchuela campground. In rodent liver/kidney tissue from the Rio Grande study area, lead residues up to 0.61 ug/g wwt were detected. These residue values are considerably lower than residues detected in samples from Panchuela and Jack's Creek campgrounds.

At Crab Orchard National Wildlife Refuge, lead residues in small mammal liver samples from control sites were less than 0.20 ug/g wwt. Small mammals from dump areas with soil lead residues from 230 to 7000 mg/l had lead residues in livers up to 0.28 ug/g wwt (Ruelle 1983). The maximum lead residue detected in soils in the Terrero Mine Waste study area was 54 mg/l at Panchuela campground.

Beyer et al. (1985) investigated lead residues in small mammals using white-footed mice as study specimens. Carcasses of mice from contaminated sites had lead residues from 7.4 to 17 ug/g dwt. In a study of small mammals to assess lead residues from highway pollution, mean lead residues in carcasses minus stomach contents varied from 9.7 to 34.8 ug/g dwt at contaminated sites and from 6.4 to 16.6 ug/g dwt at control sites (Goldsmith and Scanlon 1977). Clark (1979) also investigated the levels of lead in small mammals adjacent to a major highway to determine levels of contamination. The mammals, consisting of meadow voles and white-footed mice, were analyzed whole except for the gastrointestinal tract and any large embryos which were removed. Clark reported ranges of lead in meadow voles adjacent to a highway up to 5.0 ug/g wwt and in white-footed mice up to 41.0 ug/g wwt. At a control site, values' in meadow voles were reported up to 1.4 ug/g and in white-footed mice up to 13 ug/g wwt.

A correlation of lead exposure from carcass residues versus residues in liver/kidney tissue cannot be made. Since lead bioaccumulates in bone, most of the body burden is in the skeleton. Concentrations of lead in liver/kidney tissue represent chronic exposure due to levels present in the environment. Therefore, lead residue data from this study may underrepresent actual bioaccumulation in mammals in the study area.

The maximum concentration of lead detected in fish (1.48 ug/g wwt) was in a liver and kidney sample of brown trout from Cave Creek. Lead residues in whole-body fish samples were highest in rainbow trout above the Rio Mora. Conversely, higher lead residues in fillets were present in brown trout above Lisboa Springs Hatchery (maximum = 0.27 ug/g wwt). Because different fish species, tissues, and detection limits were used, it is not possible to determine if lead residues increased downstream. Consequently, data from the Rio Grande and the Pecos River cannot be compared except to observe that lead was not detected in whole-body samples from the Rio Grande study with the exception of the Red River (Table 7). However, data from the Terrero area support the theory of chronic lead exposure in fish.

Lead contamination in fish is slightly easier to interpret. Schmitt and Brumbaugh (1990) reported that levels of lead in fish from the NCBP in 1984 ranged from 0.01 to 4.88 ug/g wwt with a geometric mean of 0.11 ug/g wwt. The NCBP data from whole-body fish suggest that lead residues in fish from the Pecos River are elevated. Peterson et al. (1988) reported whole-body lead residues in rainbow trout generally less than 0.20 ug/g wwt. Schmitt and Finger (1987) reported on lead concentrations in edible portion fillet from largemouth bass and other fish during a study of different sample preparation techniques. In largemouth bass from a control site, lead residues in edible portion were less than 0.005 ug/g wwt. The maximum residue of lead in edible portion brown trout from the Terrero Mine Waste study was'0.27 ug/g wwt.

Sinclair (1990) described lead residues in water from mine seeps at the Terrero mine from 1.9 to 2.5 mg/l. Lead residues of 0.12 mg/l were detected below a beaver dam on Willow Creek, prior to discharging into the Pecos River. Freshwater (with a hardness of 100 mg/l) aquatic life criterion for lead is 32 ug/l and freshwater chronic criterion is 3.2 mg/l. The lead residues reported by Sinclair exceed the freshwater chronic criterion at sites downstream on Willow Creek and on the Pecos River below the Willow Creek confluence.

Although there is ample literature available related to lead and its toxic effects, there are no criteria established for safe levels for consumption over an extended period of time (Botts 1977). Eisler (1988a) offered the following criteria as evidence of wildlife contamination or human health risk: domestic livestock, less than 1.1 ug/g wwt in liver or kidney; small mammals protection, residues less than 0.05 mg/kg body weight; raptors, food intake less than 10 mg/kg body weight; and human consumption, greater than 0.3 ug/g fresh weight in edible portions. Based'upon these criteria, there is no immediate human health risk from fish consumption, except from larger fish which exceed these criteria. Lead residues in small mammals may represent a threat to predators, particularly bald eagles and other raptors. Higher lead levels are likely to be present in whole-body carcasses of mammals than were detected in this study.

Zinc

Zinc is one of the minerals that was mined at the Terrero Mine. Screening site investigations conducted at the mine and the mine dump revealed zinc concentrations ranging from 4,200 to 29,000 ug/g in the mine spoils (Sinclair 1990). Zinc is a nutritionally essential metal, and zinc toxicity in humans requires massive exposure. Zinc does not accumulate in humans with continued exposure (Goyer 1986). In domestic animals, dietary zinc requirements range from 40 to 100 mg/kg dwt daily. No adverse physiological effects were observed with diets that had zinc concentrations less than 400 mg/kg (NRC 1980). Normal residue levels of zinc in fish and wildlife tissue appear to be rather rare in the literature.

Zinc concentrations in small mammal liver/kidney samples in the Terrero area ranged from 20.83 to 33.97 ug/g wwt (geometric mean = 24.7 ug/g wwt). Zinc concentrations in small mammal liver/kidney tissue from the Rio Grande were up to 25.4 ug/g wwt (geometric mean = 24.3 ug/g). There does not appear to be any difference in zinc concentrations between small mammals collected at sites in the Terrero area and those collected from the Rio Grande. Also, there does not appear to be any difference in zinc concentration between different species or sites in the area. Beyer et al. (1985) analyzed white-footed mouse carcasses rather than liver and kidney tissues. They reported zinc residues from 145 to 192 ug/g dwt (Terrero Mine mammal carcasses = 78.3 to 133 ug/g dwt). Sileo and Beyer (1985) found zinc concentrations in deer liver (78-368 ug/g dwt) and kidney (211-454 ug/g dwt) near a zinc smelter compared to 95 to 182 ug/g dwt in liver and 103-205 ug/g dwt in kidney from deer 100 miles from the smelter. Based upon the previous studies, zinc does not appear to be elevated in mammal specimens at the campgrounds.

In edible portion fish samples from the Terrero area, zinc concentrations up to 20.88 ug/g were detected. The geometric mean of zinc in fillets of rainbow trout collected above Rio Mora was 7.8 ug/g wwt versus 16.3 ug/g wwt in fillets of brown trout collected above Lisboa Springs Hatchery. Although different fish species are involved, it appears that zinc concentrations have approximately doubled downstream. By comparison, zinc concentrations in whole-body brown trout (44.6 ug/g wwt) were also nearly double the value recorded for rainbow trout (26.6 ug/g wwt). Brown trout samples from Cave Creek had concentrations of zinc in edible portion of 22.27 ug/g wwt and in liver/kidney of 22.79 ug/g wwt. From the Rio Grande, exclusive of the Red River, zinc concentrations in whole-body brown trout ranged from 24.48 to 34.32 ug/g wwt (geometric mean = 30.63 ug/g wwt). Brown trout from the Red River (which is influenced by mine tailings) had a geometric mean zinc concentration of 36.46 ug/g wwt (Table 7).

Schmitt and Finger (1987) reported a geometric mean zinc residue in edible portion fish fillet of 9.19 ug/g wwt for three species of fish. Data from the NCBP for all fish species in 1984 indicated that whole-body zinc residues range from 9.6 to 118.4 ug/g wwt. The NCBP geometric mean was 21.7 ug/g and the 85th percentile was 34.2 ug/g wwt. Data available for zinc in surface water and seeps indicate that neither freshwater acute nor chronic criteria for aquatic life are exceeded. Sinclair (1990) reported zinc concentrations of 910 and 200 mg/l in seeps, 44 mg/l in the beaver stream, and 0.10 mg/l at the diversion on the Pecos River. The freshwater acute criterion for zinc is 120 ug/l and the freshwater chronic criterion is 110 ug/l (EPA 1986). Although zinc concentrations in fish were elevated downstream from the Terrero Mine, there is no evidence to indicate an environmental hazard to fish and wildlife. There is no human health criterion established for zinc, nor are there any recommended levels of concern for wildlife.

Mercury

Of all the inorganic compounds evaluated at the Terrero area, mercury is perhaps the most hazardous to wildlife and human health. Mercury is not an essential element for biological processes. Inorganic mercury is usually biomethylated, either by an organism upon ingestion or before ingestion by interaction with carbon compounds. Organic mercurial compounds are highly lipid-soluble and are easily absorbed. Methylmercury is particularly lipid-soluble; therefore, absorption in body fat accounts for 60 to 100 percent of intake in all species (NRC 1980).

In small mammal samples from the campgrounds in the Terrero area, mercury residues up to 0.38 ug/g wwt were detected in liver and kidney tissue. Analysis of liver and kidney samples may provide a lower estimate of mercury residues in small mammals because lipids in carcasses probably absorb more mercury. Based upon the data in Table 6, however, there is little difference between mercury residues detected at any of the campsites. The mercury levels in ground squirrels at Panchuela and Jack's Creek campgrounds may be a function of the feeding habits of the species/rather than the level of mercury present. Wren (1986) reported data describing normal levels of mercury. Wren referenced Fimreite et al. (1970) who reported residues up to 0.84 ug/g wwt (mean = 0.23 ug/g wwt) in white-footed mouse livers and up to 3.47 ug/g wwt (mean = 1.05 ug/g wwt) in Richardson's ground squirrel. The same paper presented mercury residues up to 0.07 ug/g wwt (mean = 0.04 ug/g wwt) in woodmouse liver tissue and up to 0.27 ug/g wwt (mean = 0.04 ug/g wwt) in kidney from Bull et al. (1977). These data from Bull et al. were considered to represent normal residues of mercury from a control area. Similarly, mercury data for mice from the Rio Grande (Table 7) can also be considered normal background levels. Mercury residues in the Rio Grande area ranged from less than 0.02 to 0.03 ug/g wwt. Based upon the data referenced above, mercury residues in small mammals from the Terrero area appear to be at normal background levels.

The maximum mercury residue detected in whole-body trout from the Terrero area was 0.04 ug/g wwt. Mercury residues up to 0.06 ug/g wwt (geometric mean = 0.029 ug/g wwt) were detected in edible portion fillet. There was no discernible difference in residue levels in edible portion fillets between the sample sites above the Rio Mora and above Lisboa Springs Hatchery. The sample of brown trout liver/kidney tissue had a residue level of 0.04 ug/g wwt, which falls within the range of values for fillets analyzed for this study. I n samples of brown trout (Table 7) from the Rio Grande Basin, the maximum mercury residues were 0.2 ug/g wwt in whole-body samples. In rainbow whole-body samples from the Rio Grande, the maximum detected level was 0.07 ug/g wwt. A study of mercury residues in fish from Lake Oake, South Dakota, indicates mercury residues up to 2.3 ug/g wwt in whole-body fish from areas considered contaminated, whereas fish from a control area had mercury residues up to 0.7 ug/g wwt (EPA 1973). Walter et al. (1973) reported that the higher mercury residues in fish samples from Lake Oake occurred although all water samples analyzed had mercury residues less than 0.2 ug/l. Data from the NCBP for 1984 for mercury residues in all fish species ranged from 0.01 to 0.37 ug/g wwt (geometric mean = 0.10 ug/g wwt) (Schmitt and Brumbaugh 1990).

Data on mercury residues in edible portion fillets are not readily available in the literature. However, Phillips et al. (1980) noted that mercury concentrations in fish increased with the size and age of the fish. Maximum concentrations in a particular species were: northern pike, 1.53 ug/g wwt; sauger, 1.4 ug/g wwt; walleye, 1.3 ug/g wwt; black crappie, 0.64 ug/g wwt; and white crappie, 0.60 ug/g wwt. Mercury concentration ranged from 0.18 to 0.95 ug/g wwt in axial muscle tissue of walleye from a reference site in Wisconsin (Rada et al. 1986). Kleinert and Degurse (1972) reported average mercury residues from 0.01 to 0.20 ug/g wwt (average 0.09 ug/g wwt) in fish fillets from a control area in Wisconsin. They also indicated that methylmercury represented 75 to 100 percent of detected residues.

For mercury, the current freshwater acute criterion for aquatic life protection is 2.4 ug/l and the chronic criterion is 0.012 ug/l (EPA 1986). Sinclair (1990) did not report any mercury above the detection limit of 0.005 mg/l. According to Cope et al. (1990), in low salinity water, mercury tends to accumulate to higher concentrations in fish and mercury concentrations are usually negatively correlated to pH. The relatively high pH values in the Pecos River, with the exception of the seeps reported by Sinclair (1990), may limit mercury uptake.

Currently, the maximum recommended level of mercury in food items for protection of avian predators is recognized as 0.1 ug/g wwt. To protect small mammals, mercury residues in food items should not exceed 1.1 ug/g wwt. Eisler (1987) noted that mercury contamination was evident if concentrations in kidney, brain, blood, hair, or liver tissue exceeded 1.1 ug/g. To protect human health, mercury in food items should not exceed 1.0 ug/g (EPA 1985). Based upon this recommendation, as well as information presented in the literature and a comparison of samples from other studies, mercury does not appear to be elevated in the Terrero area.

<u>Selenium</u>

Selenium is perhaps the most intensely investigated inorganic contaminant in fish and wildlife. Selenium is a beneficial trace element for both wildlife and humans; however, at high levels, it can be toxic in the environment. Selenium is similar to sulfur in its chemical properties and occurs in several oxidation states. Soluble inorganic selenites are highly toxic, as are selenite compounds (NRC 1980). The metabolic effects of selenium are highly complex. Chronic exposure to elevated levels can result in increased cellular carcinomas, while acute exposure can damage the central nervous system. Selenium in trace amounts has apparent antidotal characteristics against other carcinogenic agents such as arsenic, cadmium, and mercury (Goyer 1986).

Selenium residues in small mammal liver/kidney tissue in the Terrero area ranged from 0.46 ug/g wwt to 1.53 ug/g wwt (geometric mean = 0.835 ug/g wwt). Residues in samples of deer mice and ground squirrels are slightly higher at Panchuela campground with maximum levels of 1.53 ug/g wwt and 1.25 ug/g wwt, respectively. In mouse samples from the Rio Grande, the maximum selenium residue was 1.5 ug/g wwt with a geometric mean of 1.0 ug/g *wwt.* Normal levels of selenium in mammal livers appear to be fairly variable and depend upon the age of the animal. Clark et al. (1989) reported a geometric mean value of 1.69 ug/g wwt selenium in raccoon liver, with a maximum reported level of 5.0 ug/g wwt at a control site (Volta). By comparison Kesterson samples had a geometric mean of 19.9 ug/g wwt and a maximum value of 31 ug/g wwt. Ohlendorf (1989), reporting on studies by Clark (1987), indicated that values from a control site at Volta had average liver selenium residues of 0.228 ug/g wwt. Based upon these limited data, it would appear that selenium residues are at normal concentrations in mammals from campgrounds in the Pecos River area.

The majority of selenium data in the literature are from analysis of whole-body fish. Saiki and Lowe (1987) reported that ". . . selenium concentrations in fish muscle rarely exceed 1 ug/g wwt in the absence of geological or industrial sources." Based upon research by Gillespie et al. (1988), skeletal muscle accumulates the least amount of selenium. Maximum selenium residues of 1.4 ug/g wwt were detected in composite samples of mosquito fish at a control site at Volta (Ohlendorf et al. 1986). Fat head minnows at the Volta site had mean selenium concentrations of 2.4 ug/g dwt, and inland silverside minnow had 1.3 ug/g dwt (Ohlendorf et al. 1987). Similar levels in other studies of whole-body fish have been reported for control data (Rompala et al. 1984, Wilson and Allen 1989, Ohlendorf 1989). In 1984, selenium geometric mean concentration in all fish from the NCBP was 0.42 ug/g wwt, and the 85th percentile was 0.73 ug/g wwt (Schmitt and Brumbaugh 1990).

Residues of selenium in fillets are normally close to whole-body concentrations (Schmitt and Finger 1987). In the data from the Terrero area, selenium residues in the two composite whole-body trout samples were 0.44 ug/g wwt (rainbow) and 1.41 ug/g wwt (brown). Residues in edible portion trout fillets ranged from 0.34 to 1.41 ug/g wwt. The geometric mean selenium residue in brown trout fillets above Lisboa Springs Hatchery was 1.17 ug/g versus 0.34 ug/g in rainbow trout above the Rio Mora. Although selenium appears to increase downstream, this may be an anomaly related to the *more* piscivorous food habits of brown trout relative to rainbow trout.

Selenium concentrations in whole-body trout from the Rio Grande (Table 7) ranged from 0.21 to 1.27 ug/g wwt. Brown trout (0.57 ug/g wwt) had higher geometric mean values than rainbow trout (0.33 ug/g); however, selenium residue levels seem to be less than those in trout from the Pecos River.

Higher selenium levels were also detected in the brown trout sample at Panchuela campground. The maximum selenium level detected was 6.62 ug/g wwt in a brown trout liver/kidney sample from Panchuela campground. Fish concentrate selenium in visceral tissue, with liver accumulating selenium from 590 to 35,000 times the environmental concentration (Lemly 1985 and Gillespie et al. 1988). Peterson et al. (1988) provided data from rainbow trout liver tissue for selenium, ranging from 4.2 to 39 ug/g wwt with the low value appearing to originate from a clean site.

Selenium was not detected (i.e., less than 0.005 mg/l) in any surface water samples collected from the Pecos River or the mine seeps (Sinclair 1990). The freshwater acute criterion for selenium is 260 ug/l and the freshwater chronic criterion is 35 ug/l for aquatic life protection (EPA 1986). Saiki and Lowe (1987) reported that selenium concentrations range from 0.0001 to 0.160 mg/l and average about 0.001 mg/l in most fresh waters. For the protection of higher level predators, body burdens of selenium above 0.5 ug/g fresh weight have been considered to be harmful (Walsh et al. 1977). Selenium residues greater than 3 ug/g dwt could cause toxic effects in fish and wildlife. Selenium whole-body concentrations greater than 12 ug/g dwt or visceral residues greater than 16 ug/g dwt can cause reproductive failure in fish (Gillespie and Baumann 1986 and Lemly and Smith 1987). Eisler (1985a) reported that the maximum safe human dietary level of selenium should not exceed 5 mg/kg fresh weight. Based upon these recommendations, there does not appear to be a human health risk from selenium at the campgrounds or from eating fish fillets. Selenium residues in fish tissue also are below levels that impair fish reproduction. However, residues in fish and mammal tissue exceed the predator protection limits and may contribute to unacceptable body burdens in higher food chain organisms.

Summary

Thirty-eight biological samples of fish and mammals collected in the Pecos River and from campgrounds constructed with mine spoil from the Terrero Mine were analyzed for 23 inorganic compounds. Individual and composite samples of liver/kidney, whole-body, and edible portion fillets were analyzed. Specimens collected included golden-mantled ground squirrels, least chipmunks, deer mice, brown trout, and rainbow trout. Analytical results were compared to geochemical baseline residues in soils, as well as data for similar species from other study areas in New Mexico to determine if any elements were elevated to harmful levels. Based upon these comparisons, the following trace elements were at or below normal background levels: aluminum, antimony, barium, beryllium, boron, cobalt, chromium, iron, magnesium, manganese, molybdenum, nickel, silver, strontium, tin, and vanadium. Seven elements were elevated in samples from the Pecos River and adjacent campground areas: arsenic, cadmium, copper, lead, zinc, mercury, and selenium.

Arsenic residues in most of the samples from the Terrero area were below 0.3 ug/g wwt. The exception was an individual least chipmunk sample from Jack's Creek Campground (max = 1.83 ug/g wwt). The maximum arsenic concentration in edible portion fish was 0.3 ug/g wwt. There does not appear to be any correlation between site locations and arsenic levels in the study area. Eisler (198833) listed arsenic residues below 0.3 ug/g wwt as normal levels in environmental samples. Based upon these data, arsenic contamination in the study area is not of environmental concern.

Cadmium was detected in mammal samples of liver and kidney tissue at a maximum concentration of 1.63 ug/g wwt at Willow Creek campground. Cadmium levels in the Terrero area did not appear to be higher in any one species or at any one location. The maximum level of cadmium in fish was 0.36 ug/g wwt. The highest cadmium levels in brown trout whole-body composites (0.18 ug/g wwt) were above Lisboa Springs Hatchery. Eisler (1985b) reported that cadmium residues greater than 10 ug/g wwt in vertebrate kidney or greater than 2 ug/g wwt in whole-body is evidence of cadmium contamination. Based upon the data from this study, cadmium does not represent an environmental hazard.

Copper residues up to 27.4 ug/g dwt (6.9 ug/g wwt) in mammal liver/kidney samples are below the normal range of 30 ug/g dwt in domestic mammals reported by the NRC. Copper residues were higher in the Pecos samples than in mice from the Rio Grande samples. The maximum concentration of copper was 0.6 ug/g wwt in edible portion fish fillet and 3.38 ug/g wwt in whole-body. Average mean copper residues in whole-body fish from the Pecos River were greater than geometric mean values of copper from the 1984 NCBP. Copper residues were not higher in fish downstream from the Terrero Mine. While some samples indicate copper may be elevated, residue levels are not high enough to warrant environmental concern.

The maximum lead concentration in mammal liver/kidney tissue was 3.79 ug/g wwt. This is considerably higher than the 0.61 ug/g wwt levels detected in Rio Grande mammals. Lead residues were detected in mammals from Panchuela Creek and Jack's Creek campgrounds. The highest reported lead residue in fish was 1.48 ug/g wwt in a liver/kidney sample from Cave Creek, while the highest reported edible portion level was 0.27 ug/g wwt in brown trout collected above the Lisboa Springs Hatchery. The maximum whole-body level was 1.45 ug/g wwt in a rainbow trout sample. Normal residues of lead in whole-body fish in the NCBP range from 0.01 to 4.88 ug/g wwt (geometric mean 0.11 ug/g wwt). Average mean lead residues in whole-body fish (1.0 ug/g wwt) from the Pecos River appear elevated above the NCBP data.

Lead residues in water exceed aquatic life criteria (acute 8.2 ug/l, chronic 3.6 ug/l) (EPA 1986). Eisler (1988a) recommended a human consumption criterion of not more than 0.3 ug/g fresh weight in edible portion. Therefore, a human health risk due to consumption of fish may not currently exist; however larger fish may have much higher lead levels. In small mammals, consumption of food items greater than 0.05 ug/g may exceed wildlife protection criteria. Raptors have been noted to show clinical signs of lead poisoning at levels greater than 10 ug/g fresh weight in diet items. Higher lead residues in mammal whole-body samples have been documented in the literature. Therefore, lead residues in prey may represent an environmental hazard to raptors, particularly bald eagles. Adverse human health effects should <u>not</u> be ruled out until additional contaminant investigations are conducted.

Zinc concentrations up to 33.97 ug/g wwt were detected in mammals from the Pecos compared to maximum detected residues of 25.4 ug/g wwt from the Rio Grande. Geometric mean concentrations were similar. No differences in mammal zinc residues were noted between any of the campgrounds. The maximum zinc concentration was 20.88 ug/g wwt in edible fish fillet. Zinc residues in fish edible portion appear to be elevated above the Lisboa Springs Hatchery. Zinc residues in edible portion fish fillets are elevated in comparison to the NCBP, but are similar to residues detected in samples from the Red River, which is influenced by mine tailings. Zinc levels may not be high enough to warrant environmental concern for fish and wildlife. However, criteria to protect fish, wildlife, and human health have not been established.

The maximum level of mercury in mammal liver and kidney tissue was 0.38 ug/g wwt. No differences in mercury residues in mammals were observed between campgrounds. Mercury residues in mammal tissue at the Terrero area campgrounds were similar to levels observed from the Rio Grande and reported in the literature from noncontaminated areas. The maximum level of detectable mercury was 0.04 ug/g wwt in whole-body trout from the Pecos River and 0.06 ug/g wwt in edible portion fish fillet. Mercury residues in samples above Lisboa Springs Hatchery were no higher than those of upstream sites. Maximum mercury residues in whole-body fish from the Pecos River were less than the geometric mean value of mercury in the NCBP. Eisler (1987) reported that mercury contamination was evident if concentrations in kidney, brain, blood, hair, or liver tissue exceeded 1.1 ug/g. The recommended level of mercury in food items is 0.1 ug/g fresh weight for protection of avian predators and 1.0 ug/g for the protection of human health. Based upon these recommendations, mercury contamination does not appear to be a problem in the Terrero area.

The maximum level of selenium in small mammal liver and kidney tissue collected from campgrounds in the study area was 1.53 ug/g wwt (geometric mean = 0.835 ug/g wwt). No difference in selenium residue levels could be determined between campgrounds. Residues of selenium in small mammal tissue were similar to levels from the Rio Grande and control sites reported in the literature. Selenium residues in fish whole-body samples were 0.44 and 1.41 ug/g wwt. In edible portion fish fillets, the maximum level was 1.41 ug/g wwt. Selenium in fish samples appears to increase downstream; however, this may be due to species differences rather than environmental concentration. Selenium residues in edible portion fillets and whole-body fish were at levels similar to control sites reported in the literature. Saiki and Lowe (1987) reported that selenium residues in fish tissue are usually 1.0 ug/g wwt in the absence of geological or industrial selenium sources. Selenium residues in biological samples in the Terrero area were below levels that result in direct environmental damage or pose a risk to human health. However, selenium residues in fish and mammal tissue exceed predator protection limits and may contribute to unacceptable body burdens in high food chain organisms.

Recommendations

The study results indicate that levels of copper, zinc, lead, and selenium are elevated in some biological samples. To clarify risk factors associated with selenium and lead contamination in fish, mammals, avian predators, and human health, additional samples need to be collected. To provide statistical credibility to future studies in the study area, similar species need to be collected at each campground and river location. Sample size for terrestrial sites should be at least 10 individuals with duplicate samples. Whole-body and liver/kidney tissue samples should be analyzed. Selenium and lead should be analyzed by Graphite Furnace Atomic Absorption Spectroscopy with detection limits of 0.3 and 0.2 **ug/g** dwt, respectively. Additional fish edible portion fillet and whole-body samples should be collected and analyzed. Sample size should be 10 individuals with duplicate samples from at least six locations on the Pecos River. The control site should be above those areas influenced by mine spoil at campgrounds and roads. Another method of determining sublethal exposure to lead is by the use of enzyme blood measurements from live samples. Levels of lead in blood can be measured by using delta aminolevulenic acid dehydratase (delta-ALAD) as an indicator to determine biochemical changes. Exposure to lead causes a decrease of **delta-ALAD** (Friend 1985).

The Terrero Mine spoil piles should be stabilized to eliminate the seeps high in selenium, lead, zinc, copper and other metals. Capping the piles to minimize infiltration of rain through the mine waste would eliminate a major source of contamination in the Pecos River. To eliminate lead sources at the campgrounds, exposed areas constructed with mine tailings should either be removed or covered with noncontaminated material. Surface drainage across campground areas might also be intercepted to eliminate leaching metals and uptake by plants.

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