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Accumulation of Lead in Fish from Missouri Streams Impacted by Lead Mining

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Missouri historically has been recognized for lead production since the early 1800's and has been the primary producer of lead for the United States since 1920 (Wixson 1977). Most of this production took place in southeastern Missouri in the "Old Lead Belt" in Madison and St. Francois counties. Heavy metal mining also occurred in the "Tri-State Mining District" in southwestern Missouri. In 1955, a rich lead-zinc deposit, the "New Lead Belt," was found southwest of the Old Lead Belt (Fig. 1)

Huge piles of coarse to finely ground dolomitic residue occur throughout the Old Lead Belt and the Tri-State Mining District. The tailings contain relatively high concentrations of heavy metals (Schmidt and Finger 1982; Novak and Hasselwander 1980) and have resulted in the contamination of stream ecosystems (Jennett et al. 1981; Barks 1977; Wixson 1977; Proctor et al. 1974). Reduced standing crops of benthic organisms and elevated levels of heavy metals have been reported in streams in the Old Lead Belt (Jennett et al. 1981; Buchanan 1980; Missouri Water Pollution Board 1964). In 1977 a dam on the abandoned Desloge tailings pond in the Old Lead Belt ruptured and resulted in an estimated 90,000 cubic yards of tailings entering Big River (Novak and Hasselwander 1980). Erosion of tailings into Big River continue from this site as well as from other tailings piles in the region. Mining operations have caused significant changes in water quality and stream ecology in the New Lead Belt (Wixson 1977; Ryck 1974). Lead and other heavy metals enter streams in the New Lead Belt from smelters, mills, mine water, and tailings ponds.

This study was conducted to determine if elevated levels of lead occur in the edible tissue of fish inhabiting Missouri streams affected by lead mining.

MATERIALS AND METHODS

Three areas were sampled during this study. The first study area included a 115-mile section of Big River, located in the Old Lead Belt. Fish samples were collected at ten locations in Big River: at an upstream control near Irondale (station 1), at Leadwood (2) which is located 7 miles upstream from the ruptured Desloge tailings pond but immediately downstream from the Leadwood tailings pond and at eight sites located 3 miles (3), 15 miles (4), 25 miles (5), 40 miles (6), 58 miles (7), 75 miles (8), 85 miles (9), and 95 miles (10) downstream of the Desloge tailings pond break (Fig. 1).

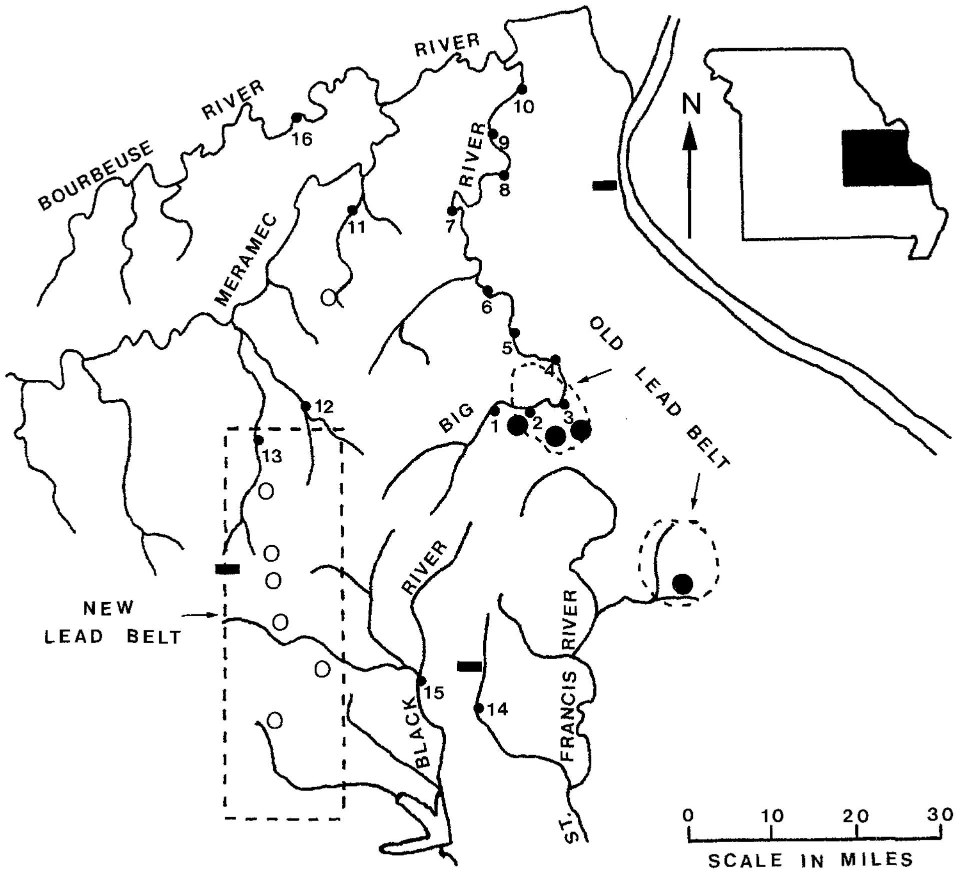

Figure 1. Location of sampling stations 1-16, abandoned lead mines and settling basins ●, active mine and mill facilities O, and smelters ▬ in the Old and New Lead Belts, southeast Missouri.

Big River is a sixth order stream based on the stream order classification system described by Horton (1945).

The next study area included five sampling locations in the New Lead Belt: Indian Creek near Piney Park (11), Courtois Creek near Berryman (12), Huzzah Creek near Davisville (13), Big Creek at Annapolis (14), Black River near Lesterville (15) and a control site on the Bourbeuse River upstream from Union (16) (Fig. 1). The five affected sample sites in the New Lead Belt were located between 8 and 22 miles downstream from lead mining and/or smelting facilities. The Black and Bourbeuse rivers are sixth order streams, Courtois, Huzzah, and Indian creeks are fifth order streams, and Big Creek is a fourth order stream.

The third study area was located in the Tri-State Mining District in southwest Missouri (Fig. 2). Samples were collected from five locations: a control station on Shoal Creek near Branby (17), a

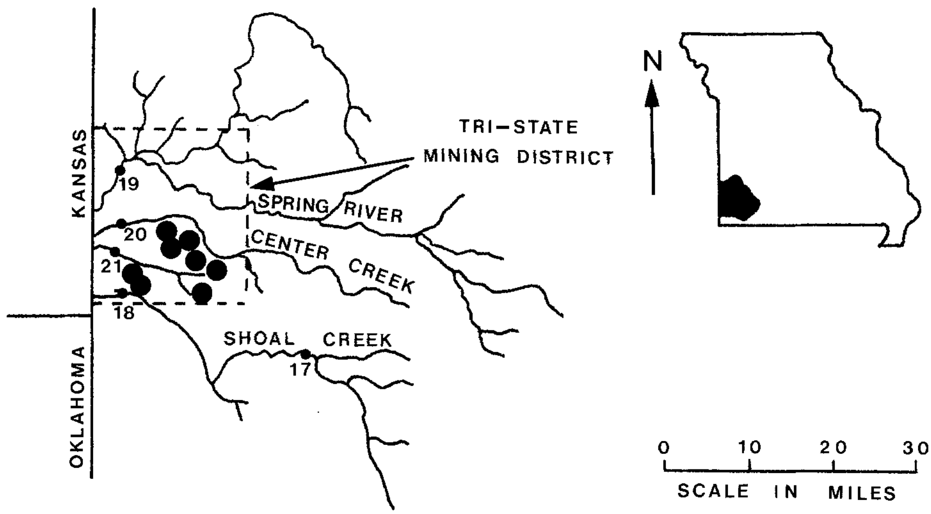

Figure 2. Location of sampling stations 17-21 and abandoned mines ● in the Tri-State Mining District, southwest Missouri.

downstream station on Shoal Creek near Joplin (18), Spring River near Waco (19), Center Creek near Carl Junction (20), and Turkey Creek near Joplin (21). These sample stations, other than the control, were located within 5 miles downstream of abandoned tailing and/or chat piles. Spring River is a seventh order stream, Center Creek a sixth order stream, Shoal Creek a fifth order stream, and Turkey Creek a fourth order stream. The normal range of pH in all streams sampled in the three study areas was 7.0 to 8.4 and the total hardness ranged from 100 to 300 mg/l $CaCO_3$.

Fish samples were collected from Big River in the Old Lead Belt on six occasions from December 1979 to June 1981. All fish samples were collected with direct current electrofishing gear. An effort was made to collect a minimum of ten black redhorse (Moxostoma duquesnei), longear sunfish (Lepomis magalotis), and smallmouth bass (Micropterus dolomieu) from each of the ten sampling sites on Big River. This minimum sample size was collected at all sites except for smallmouth bass at stations 2 (n=8), 3 (n=9), and 10 (n=7) and for longear sunfish (n=9) and black redhorse (n=9) at station 8. Golden redhorse (Moxostoma erythrurum) and northern hog suckers (Hypentelium nigricans) were also collected at some of the sample sites. Whole fish were placed on ice immediately after collection and remained on ice until we returned to our laboratory. Total length and weight were recorded for each fish. A sample of the edible tissue (scaled fillet) was taken from the left side of each fish, rinsed in tap water, placed in a clean polyethylene bag, and frozen. The sucker fillets contained the intramuscular bones. All fish tissue samples were analyzed by a private laboratory. A total of 394 fish tissue samples were collected from Big River and analyzed for lead.

Fish samples were collected from the five sample sites in the New Lead Belt and from the Bourbeuse River in December 1980. Similar species of fish were collected in these streams and samples were handled in the same manner as those from Big River. Ninety-nine fish tissue samples were analyzed for lead.

Fish samples from the Tri-State Mining District were collected in June 1981 and handled in a similar manner. Longear sunfish and black redhorse were collected at all sites except at Turkey Creek, where carp (Cyprinus carpio) were the only fish collected. Spotted bass (Micropterus punctualatus) were substituted for smallmouth bass in Center Creek, Spring River, and the downstream site on Shoal Creek. Shorthead redhorse (Moxostoma macrolepidotum) were also collected at some of the sample sites. One hundred fifty-seven fish tissue samples were analyzed for lead.

The World Health Organization's (1972) maximum recommended safe level of 0.3 parts per million lead in the diet was used as a guideline to decide if lead levels in fish might pose a threat to human health. Mean values and standard error of the mean were calculated for lead concentrations and fish lengths. Comparisons between sites and species were made using Duncan's multiple range test. Correlations were tested by Spearman's rank correlation method. Statistical significance was assumed at the 5% level ($p \geq 0.05$).

RESULTS AND DISCUSSION

Fish collected from Big River, located in the Old Lead Belt, contained the highest concentrations of lead found in fish during this study (Table 1). The concentration of lead in the edible tissue of 55 (83%) black redhorse, 23 (96%) golden redhorse, and 17 (74%) northern hog suckers collected from sites 3 through 8 (3 miles to 75 miles below ruptured dam) exceeded the World Health Organization's (1972) maximum safe level (0.3 ppm) in tissue for human consumption (Fig. 3). The mean concentrations of lead in black redhorse collected at sites 2 through 9 on Big River were significantly ($p=0.0001$) higher than the mean concentration at the control site. The highest concentration of lead found in the edible tissue of any fish was 1.30 ppm, which was found in four golden redhorse collected immediately downstream from the ruptured Desloge tailings pond at site 3.

Lead levels in longear sunfish followed a similar pattern but were lower than levels found in the suckers (Table 1). The highest concentrations of lead in longear sunfish were found immediately downstream from the mining area and the concentrations decreased progressively downstream. Twenty-six (44%) longear sunfish collected at sites 3 through 8 (3 to 75 miles below the ruptured dam) exceeded the World Health Organization's (1972) maximum safe level of lead. The highest level of lead found in a longear sunfish was 0.87 ppm at site 3. The mean concentration of lead in longear sunfish was significantly ($p=0.0001$) higher at sites 3, 4, 7, and 8 than the mean concentration at the control site.

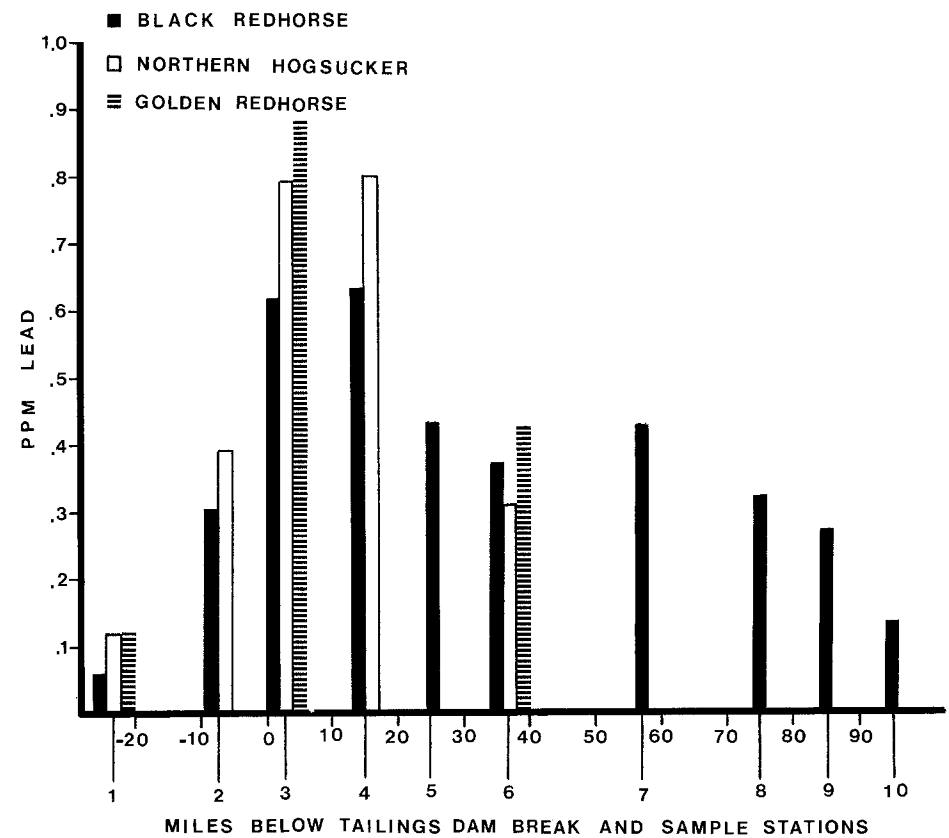

Figure 3. Mean lead concentration in the edible tissue of black redhorse, northern hog sucker and golden redhorse from Big River, Missouri.

Smallmouth bass contained lower concentrations of lead than both suckers and longear sunfish (Table 1). There was no apparent relationship between lead concentration in smallmouth bass and distance downstream from the mining area. Only 3 (5%) smallmouth bass collected from sites 3 through 8 (3 miles to 75 miles below the ruptured dam) contained lead levels which exceeded the World Health Organization's (1972) maximum safe level of lead in the diet. The highest concentration of lead found in a smallmouth bass was 0.53 ppm at site 3. The mean concentration of lead in smallmouth bass collected at sites 3 and 6 (3 miles and 39 miles below the ruptured dam) were significantly (p=0.01) higher than the mean concentration of lead in smallmouth bass collected at the control site.

The lead concentrations in longear sunfish were significantly (p=0.0001) higher than lead levels in smallmouth bass at Big River sites 4 and 7. The lead levels in fish of the sucker family were significantly (p=0.01) higher than longear sunfish and smallmouth bass at Big River sites 2, 3, 4, 5, 7, and 10 and black redhorse contained lead levels which exceeded the World Health Organization's

Table 1. Mean concentration of lead (ppm wet weight) in scaled fillets and length (inches), plus or minus standard error of the mean, for fish from Big River. Within rows, values followed by an asterisk are significantly different (Duncans multiple range test, p = 0.05) from mean values at the control, Station 1. N is sample size. ND = Not detectable. (SMB = Smallmouth bass, LESF = Longear sunfish, BRH = Black redhorse, NHS = Northern hog sucker and GRH = Golden redhorse).

Station and River Mile		SMB	LESF	BRH	NHS	GRH
1	Pb	.08±.03	.09±.03	.06±.01	.12±.05	.12±.07
RM 126	L	9.0±.6	5.4±.1	10.5±.2	10.5±.4	11.2±.4
	N	10	10	20	10	9
2	Pb	.04±.005	.14±.04	.31±.05*	.39±.08*	
RM 112	L	9.8±.1	5.6±.1	9.4±.2*	8.9±.4*	
	N	8	15	15	9	
3	Pb	.17±.06*	.39±.07*	.62±.06*	.79±.14*	.88±.07*
RM 103	L	10.2±.7	5.8±.1*	9.8±.4	9.4±.1	11.5±.3
	N	9	10	13	6	20
4	Pb	.05±.01	.35±.06*	.63±.11*	.80±.06*	
RM 90	L	12.6±1.1*	5.7±.1*	10.8±.3	8.9±.9	
	N	10	10	10	5	
5	Pb	.12±.03	.19±.03	.43±.11*		
RM 80	L	10.0±.5	5.7±.1*	10.0±.2		
	N	10	10	14		
6	Pb	.15±.03	.18±.05	.37±.03*	.31±.06	.42±.13
RM 66	L	11.8±1.0	5.3±.1	10.4±.2	11.8+.5	12.3±.1
	N	10	10	10	12	4
7	Pb	.05±.006	.27±.05*	.43±.03*		
RM 57	L	9.2±.5	5.2±.1	11.8±.4*		
	N	10	10	10		
8	Pb	.11±.02	.30±.08*	.32±.05*		
RM 31	L	10.2±.7	5.2±.2	11.5±.4*		
	N	10	9	9		
9	Pb	.10±.02	.16±.03	.27±.07*		
RM 20	L	8.8±.4	5.3+.1	11.1±.4		
	N	10	10	10		
10	Pb	N.D.	.05±.008	.13±.02		
RM 10	L	9.8+1.0	5.1±.1	11.9±.4*		
	N	7	10	10		

Table 2. Mean concentration of lead (ppm wet weight) in scaled fillets and length (inches), plus or minus standard error of the mean, for fish from streams in Missouri's New Lead Belt and the Bourbeuse River, a control stream. Within rows, values followed by an asterisk are significantly different (Duncan's multiple range test, p = 0.05). N is sample size. ND = Not detectable. (SMB = Smallmouth bass, LESF = Longear sunfish, BRH = Black redhorse and NHS = Northern hog sucker.)

Species		Bourbeuse River	Courtois Creek	Huzzah Creek	Indian Creek	Black River
SMB	Pb	.04±.007	.03±.004	.05±.01		.04±.01
	L	8.6±.6	10.9±.9	13.0±.9		9.8±.7
	N	6	10	5		3
LESF	Pb	ND		0.4±.01	.08±.04	.04±.02
	L	5.2±.1		5.9±.1	5.4±.2	5.7±.2
	N	6		4	4	4
BRH	Pb		.09±.02			
	L		9.6±.1			
			6			
NHS	Pb	.04±.01	.06±.02	[illegible]±.009	.06±.01	.07±.05
	L	10.2±.7	11.6±.7	[illegible]2±.6	10.9±.6	12.9±.4
	N	10	6	9	10	10

(1972) maximum safe limit of 0.[illegible]m in at least an 80-mile section of stream.

Lead concentrations in the edible portion of fish collected from streams in the New Lead Belt were much lower than the levels found in fish from Big River (Table 2). Lead concentrations in the edible portions of fish collected from streams in the New Lead Belt which have lead mining operations in their watersheds were not signficantly (p=0.01) different from concentrations found in fish collected from the control stream. The highest concentration of lead was 0.21 ppm in a longear sunfish collected from Indian Creek.

Lead levels in fish from Spring River Basin in the Tri-State Mining District generally were similar to those found in fish from streams in the New Lead Belt (Table 3). The only exception was in Center Creek where lead levels were slightly higher. The highest concentration of lead (0.49 ppm) was found in a carp collected from Center Creek. There was no significant (p=0.01) difference in the lead concentrations between the species of fish in any of the streams in the New Lead Belt or in the Tri-State Mining District.

Table 3. Mean concentration of lead (ppm wet weight) in scaled fillets and length (inches), plus or minus standard error of the mean for fish from Missouri streams in the Tri-State Mining District. Within rows, values followed by an asterisk are significantly different (Duncan's multiple range test, P = 0.05). N is sample size. (SMB = Smallmouth bass, SB = Spotted bass, LESF = Longear sunfish, BRH = Black redhorse, and SHRH = Shorthead redhorse).

Species		Shoal Creek (control)	Spring River	Center Creek	Shoal Creek	Turkey Creek
SMB	Pb	.04±.006				
	L	9.7±.6				
	N	10				
SB	Pb		.05±.01	.03±.006	.03±.004	
	L		9.0±.1	10.9±.8	10.6±.7	
	N		10	10	10	
LESF	Pb	.08±.02	.07±.02	.06±.02	.05±.009	
	L	4.6±.1	4.8±.1	4.4±.1	5.1±.3	
	N	10	10	10	10	
BRH	Pb	.04±.006		.04±.01	.05±.01	
	L	11.6±.4		12.9±1.8	11.7±.1	
	N	10		4	10	
SHRH	Pb		.03±.009*	.11±.03*		
	L		13.7±.4	15.7±.4		
	N		10	6		
CARP	Pb					.08±.06
	L					14.0±.3
	N					10

Lead concentrations in fish tissue did not appear to be related to size. Generally, there was no correlation between the concentration of lead and the length of fish. However, at site 6 on Big River there was a significant correlation between lead levels and length in smallmouth bass (r=0.64) and longear sunfish (r=0.91). In the New Lead Belt, the only significant correlation between length and lead levels occurred in smallmouth bass (r=0.84) at the control site on the Bourbeuse River.

Lead mining has impacted Big River more than any other Missouri stream. This is due to the close proximity of tailings deposits to the stream and poor engineering design of the dams. Current lead mining operations in the New Lead Belt are adversely affecting Missouri streams, but not to the extent that streams are being degraded in the abandoned mining areas in the Old Lead Belt.

Present milling processes are more efficient at removing lead from the ore, thus lead levels in tailings from the New Lead Belt are much lower than those in the Old Lead Belt. Stricter environmental laws also have helped to lessen the impacts of the lead mining industry on streams in the New Lead Belt.

Lead concentrations in redhorse and northern hog suckers collected downstream of the mining area in Big River exceeded values reported for fish from uncontaminated waters (Young and Blevins 1981; Oates and Stucky 1977; Kleinert and Degurse 1974). Ingestion of lead contaminated food and the incidental ingestion of sediment are the most likely means by which fish become contaminated. Suckers are benthic feeders which result in the incidental ingestion of sediment and detritus with food (Bowman 1970; Vondracek et al. 1982). It has been found that sediments made up 76% of the weight and 42% of the volume of stomach contents in blue suckers (Cycleptus elongaus) (Rupprecht and Jahn 1980) and that detritus made up 65% of the stomach contents by volume in Taho suckers (Catastomus tahoenis) (Vondracek et al. 1982).

Big River sediments contain high concentrations of lead (1,400-2,200 ppm) (Schmidt and Finger 1982) as does the organic detritus (800-7,000 ppm) (Whelan 1983). Thus, bottom feeding fish like the sucker are continually ingesting lead contaminated sediment and detritus while feeding in Big River. Longear sunfish contained intermediate lead levels, between levels found in suckers and smallmouth bass at all sites on the Big River except the control. Smallmouth bass had the lowest levels of lead which may be related to the minimal contact they have with the stream bottom while feeding and swimming. Smallmouth bass are predators and do not ingest large amounts of sediment or detritus while feeding. They spend very little time in contact with the stream bottom and are usually suspended in the water column.

The erosion of lead mine tailings into Big River has caused serious environmental degradation to a valuable aquatic resource and resulted in lead levels in suckers which exceed the maximum safe level of lead in the diet. Based on the information collected from this study, a joint recommendation was made in 1980 by the Missouri Division of Health and the Missouri Department of Conservation, that suckers caught in the 40-mile section of Big River downstream from the ruptured Desloge tailings pond dam not be consumed.

REFERENCES

Barks JH (1977) Effects of abandoned lead and zinc mines and tailings piles on water quality in the Joplin area, Missouri. U.S. Geological Survey, USGS/WRI-77-75 49 pp

Bowman ML (1970) The life history of the black redhorse, Moxostoma duquensni (LeSueur) in Missouri. Trans Amer Fish Soc 99(3):546-559

Buchanan AC (1980) Mussels (naiades) of the Meramec River basin, Missouri. Missouri Department of Conservation, Aquatic Series No. 17 68 pp

Horton RE (1945) Erosional development of streams and their drainage basins; hydrophysical approach to quantitative morphology. Bull Geol Soc Amer 56:275-370
Jennett JC, Wixson BG, Kramer RL (1981) Some effects of century old abandoned lead mining operations on streams in Missouri, USA. Minerals and Environment 3:17-20
Kleinert SJ, Degurse PE (1974) Surveys of toxic metals in Wisconsin, concentrations of metals in fish. Wisconsin Department of Natural Resources, Technical Bulletin No. 74 15 pp
Missouri Water Pollution Board (1964) Water quality of Big, Bourbeuse and Meramec River basins. Department of Public Health and Welfare in Missouri 65 pp
Novak JT, Hasselwander GB (1980) Control of mine tailings discharges to Big River. Missouri Department of Natural Resources Report 75 pp
Oates D, Stucky N (1977) Preliminary survey of heavy metal contamination of channel catfish in Nebraska. Trans Kans Acad Sci 80(1-2): 65-70
Proctor PD, Kisvarsanyi G, Garrison E, Williams A (1974) Heavy metal content of surface and ground waters of the Springfield-Joplin areas, Missouri. Pages 57-61 in D. D. Hemphill, editor. Trace substances in Environmental Health-VII. A symposium, University of Missouri, Columbia
Rupprecht RJ, Jahn LD (1980) Biological notes on blue suckers in the Mississippi River. Trans Amer Fish Soc 109:323-326
Ryck FM (1974) Water quality survey of the southeast Ozark mining area, 1965-1971. Missouri Department of Conservation, Aquatic Series No. 10 28 pp
Schmitt CJ, Finger SE (1982) The dynamics of metals from past and present mining activities in the Big and Black River watersheds, southeastern Missouri. Final Report for the U.S. Army Corps of Engineers, St. Louis District, Proj. No. DACW43-80-A-0109 142 pp
Vondracek B, Brown LR, Cech JJ (1982) Comparison of age, growth and feeding of the Tahoe sucker from Sierra Nevada streams and a reservoir. Calif Fish and Game 68(1):36-46
Whelan GE (1983) The distribution and accumulation of lead and cadmium within a lotic benthic community. M.S. Thesis, University of Missouri, Columbia 157 pp
Wixson BG, ed. (1977) The Missouri lead study, Volume I. National Science Foundation, Washington, DC 543 pp
World Health Organization (1972) Evaluation of certain food additives and of the contaminants mercury, lead, and cadmium. Sixteenth report of the Joint FAO/WHO expert committee on food additives. Geneva 33 pp
Young GJ, Blevins RD (1981) Heavy metal concentrations in the Holston River Basin (Tennessee). Archives Environ Contam Toxicol 10:541-560

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