WSRC-RP--90-482

DE91 006518

D. B. Moore
D. B. MOORE, MANAGER
AUTHORIZED DERIVATIVE CLASSIFIER

**HEAVY METALS IN FISH FROM STREAMS NEAR F-AREA AND
H-AREA SEEPAGE BASINS (U)**

Craig Loehle, Environmental Sciences Section
Mike Paller, Environmental Sciences Section

APPROVED BY: D. B. Moore
D. B. MOORE, SECTION MANAGER
ENVIRONMENTAL SCIENCES SECTION

Publication date: November 1990

Westinghouse Savannah River Company
Savannah River Site
Aiken, SC 29808

PREPARED FOR THE U.S. DEPARTMENT OF ENERGY UNDER CONTRACT NO. DE-AC90-88SR18035

MASTER

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

402

SUMMARY

This report summarizes results of recent analyses of heavy metals in fish from SRS streams near the F-Area and H-Area seepage basins. Fish were collected from headwater areas of Four Mile Creek and Pen Branch, from just below the H-Area seepage basin, and from three sites downstream in Four Mile Creek. These fish were analyzed for RCRA trace metals using standard EPA methods. Silver, arsenic, beryllium, cadmium, copper, nickel, lead, antimony, and thallium were all either undetectable or had only a few detectable values. Mercury values were all well below the regulatory limit of 1 µg/g. For the total group of fish analyzed, there were no differences among sampling sites for aluminum, chromium, or zinc. Selenium concentrations differed among sites, with fish collected near the H-Area and two control sites having the highest concentrations. When selenium concentrations were compared across sunfishes only, the seepage basin site was shown to be slightly elevated. Among species, yellowfin shiners had higher aluminum and zinc concentrations than sunfishes and bottom fish.

INTRODUCTION

Until 1988, seepage basins at F and H Areas of SRS received liquid effluents from the separations areas. These liquid wastes seeped through the ground and outcropped in the wetlands adjoining Four Mile Creek (Killian et al., 1987a,b). An issue of regulatory concern is whether the resulting contamination, components of which (Al, Zn, Mn, pH, Na) are known to have had adverse impacts on wetland vegetation (Greenwood et al., 1990), has migrated to the creek in sufficient quantity to impact fish populations. Of particular concern are RCRA metals, particularly mercury. Some of these metals have been shown to be outcropping in Four Mile Creek wetlands (Haselow et al., 1989). Previous studies (Davis et al., 1989) have also found mercury in fish above the regulatory limit of 1.0 µg/g. It is not possible to test for seepage basin impacts merely by taking water samples, because some contaminants bioaccumulate, or conversely may be regulated within the fish at a level uncorrelated with concentrations in the environment (Wiener and Giesy, 1979). Therefore, in this study we have collected several species of fish from the area of concern and compared them to upstream test locations in order to test whether fish near or downstream from the basins have accumulated metals.

In analysis of trace metals in fish, factors that need to be considered include fish size and trophic status (feeding habits). According to Wiener and Giesy (1979) in a discussion of data from Skinface Pond, near SRS:

"Except for Hg (Leland et al., 1977), there has been essentially no indication of higher concentrations of trace metals in fishes of higher trophic status relative to fishes of lower trophic status (Mathis and Cummings, 1973; Ting, 1973; Stevens and Brown, 1974; Hutchinson et al., 1976; Giesy and Wiener, 1977; Murphy et al., 1978). In addition, fishes having similar food habits may exhibit marked differences in whole body (Cross and Brooks, 1973) or tissue concentrations (Ting, 1973) of certain trace metals. Adult chain pickerel and largemouth bass are primarily piscivorous; however, mean trace metal concentrations for these species in Skinface Pond often differed significantly. Trace metal concentrations in fish are apparently related to factors other than food habits and trophic status.

Results of correlational analyses between body size and Cu, Mn, and Zn concentrations provided further empirical evidence of homeostatic regulation of these metals in fish. We found negative correlations between whole body concentrations of Cu, Mn, and Zn and total length for all species analyzed except lake chubsucker. Decreases in whole body concentrations of essential trace metals with increasing body size of fish have been reported elsewhere (Cross and Brooks, 1973; Bohn and McElroy, 1976; Giesy and Wiener, 1977; Murphy et al., 1978). However, increasing whole body concentrations of Zn with body size of fish have also been observed (Bohn and McElroy, 1976; Cutshall et al., 1977). Cross and Brooks (1973) suggested that decreases in whole body concentrations with size result from shifts in the relative proportions of body tissues that have differing metal concentrations.

Copper, Mn, and Zn concentrations in liver and axial muscle tissue were generally not correlated with body size of fish from Skinface Pond, similar to results reported elsewhere (Cross et al., 1973; Eustace, 1974; Mathis and Kevern, 1975; Pentreath, 1976; Bohn and McElroy, 1976)."

Based on this discussion, no attempt was made to include body size as a covariate, nor is it expected that trophic status will be significant.

METHODS

Adult and juvenile fish were collected during July 1990 from 6 sample stations in Four Mile Creek and one sample station in Pen Branch (Paller and Storey, 1990). The approximate locations of the sampling stations are indicated in Table 1 and Figure 1. Sites 1 and 2 represent upstream control sites on Four Mile Creek. No known sources of contamination exist in the upper reaches of the creek. Site 7 is a headwater control site on Pen Branch. Site 3 is below H-Area and is used to test for seepage basin effects. Site 4 is below the outfall from C reactor. For this study sites 4a and 4b of Paller and Storey (1990) were combined into a single site 4. Sites 5 and 6 are in the lower reaches of Four Mile Creek. At each of these sample stations, three 100 m stream segments were selected for electrofishing. Segments were measured with a measuring tape. The stream segments possessed representative habitats and were at least 30 m from roads and bridges. The segments were separated by at least 20 m.

Backpack electrofishing (Smith Root Model 15-A, 250-watt) was conducted at all sample stations. Electric current was directed around and in brushpiles, snags, stumps, beneath undercut banks, and in open water. Stunned fish were removed from the water using 6.35 mm mesh dip nets; all collections were made while moving upstream through the stream segment. A single pass was made through each stream segment.

All fish captured by electrofishing were placed on ice. Each fish was identified to species, measured (total length to nearest mm), weighed (nearest g), and briefly checked for disease, parasitism, and other anomalies in the field. Results of field analyses are reported in Paller and Storey (1990). For comparisons across sites, a fish species was needed that occurs across the entire set of sites. Sunfishes were chosen for this purpose. For comparisons among species, yellowfin shiners, yellow bullheads, and creek chubsuckers were also analyzed from sites 3 and 4. Yellow bullheads and creek chubsuckers were combined into a bottomfish category for data analysis because of insufficient numbers of the two separately. It is expected that bottomfish might accumulate metals, particularly mercury, differently. Species analyzed by site are summarized in Table 2. All captured fish were stored in clean plastic bags and frozen as soon as possible. Fish were then shipped to Roy F. Weston, Inc. for analysis using standard methods (APHA-AUWA-WPCF, 1980; EPA, 1974). Fish were gutted before analysis and the entire fish homogenized and analyzed.

Reportable metal concentrations varied among individual fish in this study because the mass of tissue varied among individual fish. Below detection limit values were handled as follows. An accepted method for filling in below detection values involves determining an appropriate distribution for the data as a whole and extrapolating to the below detection values (Newman et al., 1989). If a uniform distribution is assumed, the expectation is one-half the detection limit. For the present case, a mean detection limit (for those not reported) was computed and one-half of this used. This works well when only a few values must be interpolated, which is the case here.

A second source of data was fish previously collected at SRS and analyzed for mercury. Fish were collected in 1988 and 1989 and analyzed by WSRC Environmental Protection Department (EPD). Fish were frozen until analysis. Plugs of fish flesh (0.3g) were taken, dissolved in a nitric acid/sulfuric acid digest, and analyzed using a cold vapor technique (as specified in EPA, 1974 and APHA-AWWA-WPCF, 1980) by EPD personnel. Fish were collected at Upper Three Runs at Highway 278 (1989 only), Upper Three Runs at Road A, and Four Mile Creek east of 400 Area at Road A-13 (1989 only). This last site is close to site 6 of the present study. Fish were collected by electroshocking and larger species (bass, bream, catfish, warmouth, and sucker) were kept for analysis.

Comparison to Regulatory Limits

In addition to a comparison with control sites, it is useful to compare the data collected here with regulatory limits. Except for mercury, in which 1ppm (1 μ g/g) Hg in fish flesh is an accepted limit (EPA, 1989), regulation of trace metals in fisheries products for interstate commerce is not based on set limits but on expected human consumption levels (EPA, 1989). Regulation of local fisheries (e.g., recreational fishing on a reservoir) is left to state agencies. Determination of when to limit fishing from a local fishery is again often determined by expected dose to the typical consumer, but methods for calculating this vary greatly by state (EPA, 1989). A local fishery is often closed based on water quality rather than an analysis of human risk factors. That is, if the water is not safe to drink or swim in, then the fishery may be closed. Thus for trace metals, other than mercury, there are no regulatory guidelines for concentrations in fish.

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

RESULTS

Overall results of the analyses are presented in Table 3. Metals with only a few detectable values are discussed in the text rather than the table. Sites 1, 2, and 7 are the upstream control sites (Figure 1). Site 3 is just downstream from H-Area. Sites 4, 5, and 6 are downstream from site 3 on Four Mile Creek. One fish from site 1, upstream from all potential sources of heavy metal contamination, had consistently high concentrations of most of the metals and it was dropped as probably being an error. The following discussion compares sites based on all fish sampled. Following this comparisons by fish species are made.

Mercury

Results of prior studies are presented in Table 4. Upper Three Runs at Highway 278 is an upstream control. The 1989 data at this location shows no fish that exceed the EPA limit of 1.0ug Hg/g. Note, however, that there are no catfish from the site, which tend to be higher in mercury.

At the lower end of Upper Three Runs (at road A) the 1989 data were all under the EPA limit (including five catfish and a sucker), but for 1988 four out of seven catfish were above 1.0 ug Hg/g.

It is often found that bottom feeders exhibit more mercury accumulation (M. Newman, pers. comm.). Older and larger fish also accumulate more mercury so it is difficult to evaluate these catfish data since catfish typically are large, long-lived bottom feeders.

Data from Four Mile Creek are only available from the lower reaches for 1989. These data show only one fish that exceeded the EPA limit. However, only two catfish were sampled. From these data we can only say that if mercury from the F-and H-Area seepage basins is entering Four Mile Creek, it is either a small amount or it fails to reach the downstream segments.

Mercury results from the present study are all lower than from previous studies. The detection limit ranged from 0.004 to 0.019 mg/g, depending on individual fish weight. All of the 27 fish from control sites 1, 2, and 7 were below the detection limit, except for two from site 7 (Upper Pen Branch). There were 12 fish above the detection limit in regions 4, 5, and 6 (Table 3). These fish are all very close to the detection limit and are well below the legal limit of 1 µg/g.

Comparison of these data to the earlier HP data shows that the 1990 values are much lower. To some extent, mercury content in SRS fish could have decreased since 1988 because some sources may have been eliminated and mercury in stream sediments could have methylated, been buried, or washed out.

Silver

Detection limits for silver ranged from 0.095 to 0.71 $\mu\text{g/g}$. Only one fish, from site 3, had a reportable value at 0.55 $\mu\text{g/g}$, which is only slightly above the detection limit for most of the fish.

Aluminum

Detection limits for aluminum ranged mostly around 2 to 5 $\mu\text{g/g}$, with one going as high as 33. All but six fish were above the detection limit. The mean detection limit value was 2.3 except for two fish whose detection limits of 9.5 and 33 were higher than most of the detected values. These two values were treated as missing. The other four had 1.15 substituted for below detection values (half of the mean detection limit). No difference was detectable across the seven sites when all fish were lumped (ANOVA $R^2 = .067$, $p = 0.4$).

Site	N	Mean ($\mu\text{g/g}$)	SD
1	9	17.6	8.73
2	9	13.9	5.94
3	23	13.3	6.59
4	29	18.2	13.20
5	7	10.9	9.12
6	10	12.7	10.41
7	8	17.0	8.50

Arsenic

Detection limits for arsenic were mostly in the range 0.07 to 0.08 $\mu\text{g/g}$. Only three fish were above the detection limit: two at site 4 (0.13 and 0.088 $\mu\text{g/g}$) and one at site 7 (Pen Branch) at 0.26 $\mu\text{g/g}$.

Beryllium

Detection limits for beryllium were in the range 0.03 to 0.3 µg/g. All samples were below this limit.

Cadmium

Detection limits for cadmium were mostly in the range 0.048 to 0.83 µg/g. Only six samples exceeded this level, all from site 4, with values 0.053, 0.21, 0.16, 0.055, 0.07, and 0.13 µg/g. These values are the same order of magnitude as the detection limit and thus may not be very meaningful.

Chromium

Detection limits for chromium were mostly in the range 0.1 to 0.2 µg/g. All but 10 of the samples exceeded this level. One sample had a detection limit (1.7 µg/g) higher than any reported value and was excluded. The other 9 below detection values were replaced with half the average detection limit, or 0.205 µg/g. No differences between regions were evident (ANOVA $R^2 = 0.03$, $p = 0.85$).

Site	N	Mean (µg/g)	SD
1	9	0.46	0.50
2	9	0.33	0.18
3	23	0.39	0.15
4	30	0.46	0.30
5	7	0.49	0.34
6	10	0.46	0.19
7	8	0.42	0.26

Copper

Detection limits for copper mostly ranged from 0.2 to 0.7 µg/g. Only three samples at site 4 (18.1, 28.2, and 0.34 µg/g), two at site 5 (0.32 and 0.27 µg/g) and one at site six (0.25 µg/g) exceeded these limits. Only the first two of these were much above the detection limits.

Nickel

Detection limits for nickel were mostly in the range 0.4 to 0.9 $\mu\text{g/g}$. Only two samples, from site 4, exceeded this level, with values of 2.2 and 12 $\mu\text{g/g}$.

Lead

Detection limits for lead were mostly in the range 0.01 to 0.89 $\mu\text{g/g}$. While 39 values were above the detection limit, only two from site 4 exceeded 0.89 $\mu\text{g/g}$ at 1.3 and 2.2 $\mu\text{g/g}$. With the large number of below reporting limit values and the closeness of all but two values to the detection limit, it is not possible to do any statistical testing.

Antimony

Detection limits for antimony were mostly in the range 0.5 to 2.0 $\mu\text{g/g}$. Three samples from site 3 (at 0.68, 3.0, and 1.9 $\mu\text{g/g}$) and two from region 4 (at 3.8 and 2.8 $\mu\text{g/g}$) were above this level. Even these values are very close to the detection limit.

Selenium

Detection limits for selenium were mostly in the range 0.1 to 0.2 $\mu\text{g/g}$. Seventeen samples fell below this level. Below detection limit values were replaced with half the mean detection limit, 0.058 $\mu\text{g/g}$. No evidence for site differences was evident. The overall ANOVA was significant, but the highest means were at sites 1, 2, 3 and 7. A test of selenium concentrations at sites 1, 2, 7 (the three control sites) vs. 3 using linear contrasts was not significant at the 0.05 level.

Site	N	Mean ($\mu\text{g/g}$)	SD
1	9	0.34	0.33
2	9	0.21	0.05
3	23	0.37	0.23
4	31	0.21	0.12
5	7	0.07	0.03
6	10	0.10	0.06
7	8	0.29	0.11

Thallium

All samples were below the detection limit, which ranged from 0.1 to 0.5 µg/g.

Zinc

All samples were above the detection limit for zinc. No differences between sites were evident (ANOVA $R^2 = 0.05$, $p = 0.56$).

Site	N	Mean (µg/g)	SD
1	9	16.86	5.03
2	9	18.93	9.28
3	23	21.81	9.74
4	31	27.44	25.67
5	7	19.46	5.79
6	10	22.23	5.08
7	8	19.74	7.66

Analysis by Species

In order to test for differences between species, several analyses were performed. Sunfishes were collected at all sites. When they were analyzed independently of the other species, selenium was found to differ by site (ANOVA $R^2 = 0.51$, $p < 0.01$):

Selenium in Sunfish

Site	N	Mean (µg/g)	SD
1	9	0.34	0.33
2	9	0.21	0.05
3	10	0.59	0.17
4	16	0.24	0.15
5	7	0.07	0.03
6	10	0.10	0.06
7	8	0.29	0.11

When control sites 1, 2, and 7 were lumped and compared to 3 using linear contrasts, the result was still significant ($p < 0.01$). No other metal showed a site difference based on sunfishes alone. At sites 3 and 4 multiple species were collected. The sunfishes, shiners, and bullheads plus suckers (bottom fish) were compared. Selenium showed a species difference, but due to sunfishes being higher at site 3 (as shown above). Shiners showed elevated aluminum compared to the other species (ANOVA $R^2 = 0.11$, $p = 0.06$):

Aluminum Among Species

Species	N	Mean ($\mu\text{g/g}$)	SD
Sunfishes	26	15.35	6.27
Shiners	12	22.00	18.82
Bottom fish	14	12.10	6.84

The same trend was evident for zinc (ANOVA $R^2 = 0.29$, $p < 0.01$):

Zinc Among Species

Species	N	Mean ($\mu\text{g/g}$)	SD
Sunfishes	26	19.78	6.51
Shiners	13	44.29	34.57
Bottom fish	15	17.49	5.83

CONCLUSIONS

Silver, arsenic, beryllium, cadmium, copper, nickel, lead, antimony, and thallium were all either undetectable or had only a few detectable values. Mercury values were all well below the regulatory limit of $1 \mu\text{g/g}$. Across all fish, there were no site differences for aluminum, chromium, or zinc. Selenium showed a site effect, with control sites and site 3 being highest. When selenium was tested using sunfishes only, site 3 was shown to be slightly elevated. Across species, yellowfin shiners in sites 3 and 4 were higher in aluminum and zinc. Since all species were not collected at all sites the reason for shiners having elevated levels is not testable. It could be due to species differences alone or it could result from uptake of contaminants.

REFERENCES

- APHA-AUWA-WPCF, 1980, *Standard Methods for the Examination of Water and Waste Water*. #303 *Determination of Mercury by the Cold Vapor Technique*.
- Bohn, A., and R. O. McElroy, 1976, Trace metals (As, Cd, Cu, Fe, and Zn) in Arctic cod, *Boreogadus saida*, and selected zooplankton from Strathcona Sound, northern Baffin Island. *J. Fish Res. Board Can.* 33: 2836-2840.
- Cross, F. A., and J. H. Brooks, 1973, Concentrations of manganese, iron, and zinc in juveniles of five estuarine-dependent fishes, p. 769-775. In D. J. Nelson [ed.] *Radionuclides in ecosystems*, Vol. 2, Proc. *Third Nat. Symp. Radioecol.*, U.S. Atomic Energy Comm., Symp. Ser. CONF-710501.
- Cutshall, N. H., J. R. Naidu, and W. G. Pearcy, 1977, Zinc and cadmium in the Pacific hake *Merluccius productus* off the western U.S. coast. *Mar. Biol.* 44: 195-201.
- Davis, H. A., D. K. Martin, and J. L. Todd, 1989, *Savannah River Site Environmental Report for 1988*. WSRC-RP-89-59-1. WSRC, Aiken, SC 29808.
- EPA, 1974, *EPA Methods for Chemical Analysis of Water and Wastes*. EPA-600. #245.1. *Mercury Manual Cold Vapor Technique*.
- EPA, 1989, *Assessing Human Health Risks from Chemically Contaminated Fish and Shellfish: A Guidance Manual*. EPA-503/8-89-002.
- Eustace, I. J., 1974, Zinc, cadmium, copper and manganese in species of finfish and shellfish caught in the Derwent Estuary, Tasmania. *Aust. J. Mar. Freshwat. Res.* 25: 209-220.
- Giesy, J. P. Jr., and J. G. Wiener, 1977, Frequency distributions of trace metal concentrations in five freshwater fishes. *Trans. Am. Fish. Soc.* 106: 393-403.
- Greenwood, K. P., M. E. Hane, A. J. Lander, C. Loehle, and C. J. Richardson, 1990, *Assessment of Tree Toxicity Near the F and H Area Seepage Basins of the Savannah River Site*. WSRC-TR-90-253. WSRC Savannah River Lab, Aiken, SC.
- Haselow, J., M. Harris, B. B. Looney, N. V. Halverson, and J. B. Gladden, 1990, *Analysis of Soil and Water at the Four Mile Creek Seepage near the F&H Areas of SRS*. WSRC-RP-90-591. WSRC Savannah River Laboratory, Aiken, SC 29808.

Hutchinson, T. C., A. Fedorenko, J. Fitchko, A. Kuja, J. Van Loon, and J. Lichwa, 1976, Movement and compartmentalization of nickel and copper in an aquatic ecosystem, p. 565-585. In J. O. Nriagu [ed.] *Environmental biogeochemistry, Vol. 2, Metals transfer and ecological mass balances*. Ann Arbor Science Publishers Inc., Ann Arbor, Mich.

Killian, T. H., N. L. Colb, P. Corbo, and I. W. Marine, 1987a, *Environmental Information Document F-Area Seepage Basin*. DPST-87-704. E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, SC.

Killian, T. H., N. L. Colb, P. Corbo, and I. W. Marine, 1987b, *Environmental Information Document H-Area Seepage Basin*. DPST-87-706. E. I. du Pont de Nemours and Company, Savannah River Laboratory, Aiken, SC.

Leland, H. V., S. N. Luoma, and D. J. Wilkos, 1977, Heavy metals and related trace elements. *J. Water Pollut. Control Fed.* 49: 1340-1369.

Mathis, B. J., and T. F. Cummings, 1973, Selected metals in sediments, water, and biota in the Illinois River, *J. Water Pollut. Control Fed.* 45: 1573-1583.

Mathis, B. J., and N. R. Kevern, 1975, Distribution of mercury, cadmium, lead and thallium in a eutrophic lake. *Hydrobiologia* 46: 207-222.

Murphy, B. R., G. J. Atchison, A. W. McIntosh, and D. J. Kolar, 1978, Cadmium and zinc content of fish from an industrially contaminated lake. *J. Fish Biol.* 13: 327-335.

Newman, M. C., P. M. Dixon, B. B. Looney, and J. E. Pinder, III, 1989, Estimating Mean and Variance for Environmental Samples with Below Detection Limit Observations. *Water Resources Bull.* 25: 905-916.

Paller, M., and C. Storey, 1990, Effects of Outcropping Groundwater from the F- and H-Area Seepage Basins on the Distribution of Fish in Four Mile Creek. WSRC-TR-90-502. WSRC Savannah River Laboratory, Aiken, SC 29808.

Pentreath, R. J., 1976, Some further studies on the accumulation and retention of ^{65}Zn and ^{54}Mn by the plaice, *Pleuronectes platessa*. *L. J. Exp. Mar. Biol. Ecol.* 21: 179-189.

Stevens, J. D., and B. E. Brown, 1974, Occurrence of heavy metals in the blue shark *Prionace glauca* and selected pelagic fish in the N. E. Atlantic Ocean. *Mar. Biol.* 26: 287-293.

Ting, R. Y., 1973, Distribution of Zn, Fe, Mn, and Sr in marine fishes of different feeding habits, p. 709-720. In D. J. Nelson [ed.] Radionuclides in ecosystems, Vol. 2, *Proc. Third Nat. Symp. Radioecol., U. S. Atomic Energy Comm. Symp. Ser.* CONF-710501.

Wiener, J.G., and J.P. Giesy, Jr., 1979, Concentrations of Cd, Cu, Mn, Pb, and Zn in Fishes in a Highly Organic Softwater Pond. *J. Fish. Res. Board Can.* 36: 270-279.

TABLE 1. Sampling site locations of Four Mile Creek (FMC) and Pen Branch (PB).

Site	Location
1	FMC at Road F (below bridge)
2	FMC at Road 4
3	FMC at Road C
4	FMC at Road 3
5	FMC at West end of Banana Road (power line corridor)
6	FMC at Cassels Pond (2 miles below Road A)
7	PB at Road B

TABLE 2. Numbers of Fish Analyzed by Species at Each Sampling Site

Site	Redbreast Sunfish	Spotted Sunfish	Dollar Sunfish	Yellow Bullhead	Creek Chubsucker	Yellowfin Shiner
1	10					
2	2	7				
3	10			3	6	2
4	16			7	2	6
5	7					
6	10					
7	3	3	2			

TABLE 3. Laboratory Values for Fish Tissue Concentrations. Fish species codes are 1 for sunfishes, 2 for yellowfin shiner, and 3 for yellow bullhead and creek chubsucker.

µg/g Wet Weight

Site	Fishsp	Aluminum	Chromium	Lead	Selenium	Zinc	Mercury
1	1	19.3	0.27	.	0.31	19.5	.
1	1	24.3	0.24	.	0.17	22	.
1	1	7.4	0.18	0.066	0.18	6.3	.
1	1	27.1	1.8	0.16	0.19	22.5	.
1	1	8.1	0.32	0.065	0.21	13.4	.
1	1	30.4	0.28	0.065	0.32	17	.
1	1	9.8	0.38	.	0.2	18.4	.
1	1	11.1	0.4	0.095	0.31	18.6	.
1	1	88	.	.	1.2	77.2	.
1	1	20.8	0.34	0.38	1.2	14	.
2	1	18.2	0.42	.	0.19	23.1	.
2	1	10.4	0.53	.	0.18	23.1	.
2	1	4.3	.	.	0.21	7	.
2	1	13.4	.	0.13	0.31	36.7	.
2	1	11.6	.	.	0.15	9.6	.
2	1	9.4	.	0.069	0.21	11.4	.
2	1	17.1	0.3	.	0.2	15.5	.
2	1	15.4	0.22	0.26	0.18	18.7	.
2	1	24.9	0.7	.	0.25	25.3	.
3	1	6.7	0.25	.	0.52	10.3	.
3	1	20.7	0.44	0.085	0.89	22.1	.
3	1	7.1	0.22	.	0.52	12.6	.
3	1	22.2	0.53	.	0.31	32.5	.
3	1	16.6	0.27	.	0.76	23.1	.
3	1	13.5	0.24	.	0.47	11.2	.
3	1	14.1	0.35	.	0.67	16	.
3	1	11.3	0.24	.	0.45	16.5	.
3	1	5.3	0.18	.	0.58	15	.
3	1	12.6	0.46	0.13	0.71	32.1	.
3	2	24	0.39	0.094	0.33	30.3	.
3	2	11.7	0.2	0.12	.	28.2	.
3	2	21.4	0.36	.	0.22	54.5	.
3	2	9.8	0.3	.	0.37	28.7	.
3	3	11.8	0.44	0.6	0.14	14.2	.
3	3	8.1	0.33	0.06	0.19	15.5	.
3	3	9.7	0.54	0.11	0.21	20.2	.
3	3	27.9	0.52	.	0.18	21.4	.
3	3	6	0.74	0.068	0.21	15.9	.
3	3	10.7	0.5	0.068	0.25	19.5	.
3	3	15.1	0.64	.	.	26.4	.
3	3	2	0.22	0.34	0.29	16.2	.
3	3	17.6	0.53	0.36	0.14	19.3	.

TABLE 3. (Continued)

Site	Fishsp	Aluminum	Chromium	Lead	Selenium	Zinc	Mercury
4	1	.	0.47	.	.	21	0.007
4	1	24.5	0.37	.	0.54	17.1	.
4	1	13.4	0.68	0.13	0.21	32.5	.
4	1	17.3	0.39	.	0.14	16.6	.
4	1	19.4	0.41	0.07	.	21.9	.
4	1	20.5	0.41	0.043	0.34	17.8	.
4	1	23.4	0.35	.	0.53	21.4	.
4	1	16.1	0.33	.	0.28	16.2	.
4	1	19.9	0.67	0.082	0.18	17.8	.
4	1	21.3	0.45	.	.	31.4	.
4	1	12	0.29	.	0.25	15.6	.
4	1	25.6	0.56	.	0.2	25.8	.
4	1	13.9	0.18	.	0.36	11.8	.
4	1	17.9	0.49	.	0.23	18.7	.
4	1	14.3	0.44	.	.	18.8	.
4	1	8.4	0.33	0.057	0.28	18.4	.
4	2	30.2	0.45	0.35	0.12	16.9	.
4	2	49.9	1.3	0.66	0.21	57	.
4	2	3.7	0.25	0.02	0.16	13.9	.
4	2	.	0.17	1.3	0.21	22.7	.
4	2	21.5	1.4	2.2	0.22	13.8	.
4	2	3.7	0.18	0.04	0.16	9.5	.
4	2	.	.	0.1	0.35	79.1	.
4	2	63	1	.	.	48.6	.
4	2	23.9	0.58	0.08	0.18	48.4	.
4	3	13.6	0.29	.	.	15.3	.
4	3	6.4	0.43	0.18	0.22	11	.
4	3	21.1	0.33	.	0.22	18.9	.
4	3	5.9	0.23	0.12	0.15	8.4	.
4	3	13.5	0.22	0.11	0.22	10	.
4	3	.	.	0.53	0.14	30.1	.
5	1	24.2	0.63	.	.	24.6	.
5	1	12.4	0.17	0.067	0.12	8	0.007
5	1	21.4	0.31	.	.	16.8	.
5	1	3.4	0.34	.	.	18.9	0.01
5	1	2.1	1.2	.	.	24.6	0.039
5	1	10.7	0.36	.	0.11	21.5	0.01
5	1	2.2	0.42	.	.	21.8	.
6	1	37.7	0.47	.	0.11	24.7	0.007
6	1	10.5	0.65	.	.	22.7	0.007
6	1	10.9	0.35	.	0.17	24.8	0.008
6	1	18.6	0.39	.	0.18	27.7	0.008
6	1	5.8	0.9	.	.	25	0.007
6	1	2.8	0.3	.	.	13.1	.
6	1	13.5	0.21	.	.	13.1	0.014
6	1	16.5	0.43	.	.	26	0.007

TABLE 3. (Continued)

Site	Fishsp	Aluminum	Chromium	Lead	Selenium	Zinc	Mercury
6	1	.	0.41	.	0.17	22.8	.
6	1	9.1	0.49	.	.	22.4	.
7	1	17.2	0.45	.	0.27	17.1	0.24
7	1	26.7	0.66	.	0.36	34.9	.
7	1	16.4	0.43	.	0.26	17.8	.
7	1	18.1	.	.	0.16	26	.
7	1	15.6	.	.	0.22	17.7	.
7	1	12.1	.	.	0.41	11.8	0.038
7	1	.	0.26	.	0.2	11.8	.
7	1	28.5	0.92	0.89	0.47	20.8	.

* . represents below laboratory reporting limit

TABLE 4. Mercury Data For Fish from Earlier Studies**Upper Three Runs at Highway 278**

1989 DATA	$\mu\text{g Hg/g}$
Bass	0.90
Bass	0.73
Bass	0.81
Bream	0.30
Bream	0.67
Bream	0.67
Bream	0.32
Bream	0.43
Bream	0.25
Warmouth	0.40
Warmouth	0.40

**Four Mile Creek
(E of 400 Area at Road A-13)**

1989 DATA	$\mu\text{g Hg/g}$
Bass	0.80
Bass	2.41
Bass	0.95
Bass	0.78
Bass	0.86
Bass	0.17
Bass	0.56
Bream	0.12
Bream	0.70
Bream	0.74
Bream	0.40
Bream	0.42
Catfish	0.42
Catfish	0.10

TABLE 4. Mercury Data For Fish from Earlier Studies (Contd)

Upper Three Runs at Road A

1989 DATA	ug Hg/g
Bass	0.12
Bass	0.95
Bass	0.79
Bream	0.11
Bream	0.18
Bream	0.26
Bream	0.54
Bream	0.49
Bream	0.55
Bream	0.42
Catfish	0.31
Catfish	0.36
Catfish	0.10
Catfish	0.43
Catfish	0.67
Sucker	0.53
1988 DATA	ug Hg/g
Bream	0.05
Bream	0.14
Bream	0.08
Bream	0.20
Bream	0.03
Bream	0.19
Bream	0.22
Catfish	0.38
Catfish	2.00
Catfish	1.13
Catfish	2.02
Catfish	2.52
Catfish	0.00
Catfish	0.74

Figure 1. Fish Sampling Locations.

END

DATE FILMED

02 / 08 / 91