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Summary Biomonitoring Report
for
IR Site 56 - IW87 Lead Contaminated Outfall

Indian Head Division
Naval Surface Warfare Center
Indian Head, Maryland

Engineering Field Activity Chesapeake
Naval Facilities Engineering Command
Contract Number N62472-90-D-1298
Contract Task Order 0117

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SUMMARY BIOMONITORING REPORT
FOR
IR SITE 56 - IW87 LEAD CONTAMINATED OUTFALL

INDIAN HEAD DIVISION
NAVAL SURFACE WARFARE CENTER
INDIAN HEAD, MARYLAND

COMPREHENSIVE LONG-TERM
ENVIRONMENTAL ACTION NAVY (CLEAN) CONTRACT

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EXECUTIVE SUMMARY

Biomonitoring in the IR Site 56 pond has not detected any evidence that elevated levels of lead in the sediments are accumulating in the fish.

Site 56 is an Navy Installation Restoration (IR) Program site at the Indian Head Division, Naval Surface Warfare Center in Indian Head, Maryland. Lead was discharged into the environment at Site 56 through a drain pipe which outlets into a stream (Site 56 stream). The stream then flows into a pond (Site 56 pond). Elevated levels of lead were detected in the Site 56 stream and pond. Five rounds of biomonitoring were performed to assess the impact of elevated levels of lead in the sediments of the Site 56 Pond.

Lead levels in the Site 56 stream and pond sediments are elevated, however, there are no obvious corresponding elevated levels of lead in the Site 56 fish. The lead levels in the fish are generally comparable to fish from a variety of aquatic habitats in the eastern U.S. Lead concentrations in Site 56 fish tend to be higher in some fish species (brown bullhead and gizzard shad) that feed or scavenge on the bottom, but are not elevated in a variety of game fish (bluegill, white crappie, black crappie, and largemouth bass). Lead concentrations in the Site 56 fish tend to be lower than those reported for fish from streams in other parts of Maryland.

Biomonitoring data suggest that lead in the Site 56 sediments may be in a form that is not readily bioavailable and that biota are not accumulating lead to a significant degree. There is no evidence of food chain biomagnification and no evidence to suggest that fish at Site 56 have been significantly affected by elevated levels of lead in the sediments.

1.0 INTRODUCTION

The Northern Division of the Naval Facilities Engineering Command issued Contract Task Order Number 0117 (CTO 117) to Brown & Root Environmental, a Division of Halliburton NUS Corporation (hereafter referred to as B&R Environmental) in 1993 under Comprehensive Long-term Environmental Action Navy (CLEAN) Contract No. N62472-90-D-1298. Under CTO 117, B&R Environmental initially performed quarterly biomonitoring for Installation Restoration (IR) Site 8 - Nitroglycerin Plant Office (Site 8). Site 8 contained elevated levels of mercury and the initial objective of the Biomonitoring Program was to assess its impact on the environment.

During implementation of the biomonitoring program for mercury, elevated levels of lead were detected in some of the sediments of the stream and pond. This newly identified area was designated Installation Restoration (IR) Site 56 - IW87 Lead Contaminated Outfall. The biomonitoring program was expanded in 1993 to assess the impact of lead at Site 56.

Lead was discharged into the stream and pond sediment through a pipe which discharged lead-contaminated water into the environment. The stream and pond into which the water was discharged were designated the Site 56 stream and Site 56 pond. Both are coincidental with the previous Site 8 designations. In the October 1993, and April and October 1994 rounds of biomonitoring, fish and turtle samples from Site 56 pond were analyzed for lead as well as mercury, and the results of lead analyses were included in quarterly biomonitoring reports (Halliburton NUS, 1993; Halliburton NUS, 1994; Halliburton NUS, 1995a). Field work for the mercury biomonitoring program was completed in January 1995. However, two additional rounds of biomonitoring for lead were proposed for Site 56. B&R Environmental prepared a Supplemental Biomonitoring Plan (Halliburton NUS 1995b) which described two additional quarterly rounds of biomonitoring (summer and fall 1995) for lead at the Site 56 pond. Field work was performed during the first week of August and the first week of November 1995.

This report presents the results of the fall 1995 round of supplemental biomonitoring and summarizes the results of the four previous rounds of biomonitoring of lead in Site 56. The supplemental (summer and fall 1995) biomonitoring was conducted in accordance with the Supplemental Biomonitoring Plan (Halliburton NUS, 1995b).

2.0 MATERIALS AND METHODS

For the fall 1995 round, Coastal Environmental Services, Inc. (Coastal), a subcontractor to B&R Environmental, collected fish from the Site 56 Pond on November 2 and 3, 1995. This sampling was performed to assess the degree to which lead has moved into the food chain. Coastal employed a variety of active and passive sampling techniques in an attempt to collect fish from four trophic groups (insectivore/surface feeder, omnivore/sunfish, bottom feeder, top carnivore) as described in the Supplemental Biomonitoring Plan (Halliburton NUS, 1995b).

Fish samples were collected using seines, electrofishing gear, trap nets and gill nets. Active sampling gear included a 50-foot beach seine and a smaller custom seine designed to collect fish in narrow swales, backwater sloughs, and shallow littoral areas. Electrofishing gear (a conventional battery-powered unit manufactured by Smith-Root) was used to sample fish along pond margins in areas too weedy or too difficult to seine because of shallow water or submerged debris. The passive gear consisted of two Indiana-style trap nets and two 150-foot long experimental mesh gill nets. Trap nets and gill nets were set on the afternoon of November 2nd and retrieved the following morning. Total fishing time for trap nets and gill nets was 16 to 20 hours. All fish retained for analysis were placed on ice and shipped to Gascoyne Laboratories, Inc. for analysis of lead residues in tissue.

3.0 RESULTS AND DISCUSSION

3.1 NOVEMBER 1995 ROUND OF BIOMONITORING

A variety of fish species were collected in November 1995 using the active and passive sampling gear described previously. Gill nets were particularly productive, capturing relatively-high numbers of fish representing a mix of species (e.g., gizzard shad, brown bullhead, largemouth bass, and common carp). Trap nets were not as productive as gill nets, but did capture small numbers of fish (e.g., creek chubsucker, white and black crappie) and turtles. The backpack electrofisher produced a substantial number of small bluegill (more than 20) as well as small numbers of largemouth bass and brown bullhead. Numerous small bluegill and small numbers of crappie and creek chubsucker were captured with the large beach seine. No fish were collected with the small custom seine, suggesting that fish had moved into deeper water with cooler weather.

When available, larger (presumably older) fish were submitted to the laboratory as one or two fish per discrete lab sample. When only smaller fish were captured, composite samples of three or more fish were submitted to the analytical lab. Table 3-1 shows the number and sizes of fish that were sent to the laboratory for analysis.

Whole-body samples of fish were analyzed for total lead using the analytical method described in EPA SW846 Method 7421. The minimum detection limit was 0.2 mg/kg (equivalent to ppm). Results of these tissue analyses are presented in Table 3-2.

Lead concentrations in Site 56 fish in November ranged from nondetectable (a sample of two largemouth bass) to 1.2 mg/kg (a composite sample of brown bullhead). There was no evidence of biomagnification: the highest concentration was found in a species (brown bullhead) that is (depending on age of fish, time of year, and habitat) a bottom-feeding omnivore that eats crustaceans, insects, algae, mollusks, and small fish (Tomelleri and Eberle, 1990; Rohde et al., 1994). Low levels of lead were observed in composite samples of piscivorous white crappie and black crappie; however, these samples were comprised of relatively small fish, most of which would have been less than 3 years old based on growth rates in the scientific literature (Carlander, 1977). Goldfish (an omnivore and scavenger), creek chubsucker (a bottom-feeding omnivore), and bluegill (an omnivore that is primarily insectivorous when young, but increasingly piscivorous as it gets older and larger) all contained 0.4 mg/kg of lead.

TABLE 3-1

FISH SAMPLES FROM SITE 56 POND SUBMITTED FOR ANALYSIS
INDIAN HEAD DIVISION, NSWC
INDIAN HEAD, MARYLAND
NOVEMBER 1995

Fish		Sample Size (Number)	Total Length (range, in inches)	Total Weight (ounces)
Common Name	Scientific Name			
Gizzard shad	*Dorosoma cepedianum*	6	7.0 - 13.0	2 lbs 14 oz
Goldfish	*Carassius auratus*	3	10.3 - 11.8	2 lbs 11 oz
Carp	*Cyprinus carpio*	1	17.5	2 lbs 9 oz
Carp	*Cyprinus carpio*	1	17.0	2 lbs 11 oz
Creek chubsucker	*Erimyzon oblongus*	2	7.0 - 9.0	8.7 oz
Brown bullhead	*Ameiurus nebulosus*	4	6.5 - 9.0	16.4 oz
Bluegill	*Lepomis macrochirus*	12	4.0 - 6.0	14.6 oz
Black crappie	*Pomoxis nigromaculatus*	6	6.0 - 7.0	16.4 oz
White crappie	*Pomoxis annularis*	2	7.3 - 7.5	7.1 oz
Largemouth bass	*Micropterus salmoides*	2	10.5 (both)	1 lb 3 oz

TABLE 3-2

LEAD CONCENTRATION IN SITE 56 FISH TISSUE
INDIAN HEAD DIVISION, NSWC
INDIANA HEAD, MARYLAND

Location	Organism	Lead Concentrations (mg/kg)				
		October 1993	April 1994	October 1994	August 1995	November 1995
Site 56 Pond	Gizzard Shad	—	—	—	1.6	0.7
	Goldfish	—	—	—	0.3	0.4
	Common Carp	—	<0.2	<–	0.4	<0.2/<0.2
	Creek Chubsucker	—	—	—	0.4	0.4
	Brown Bullhead	10 U	—	0.5	—	1.2
	Mosquitofish (Gambusia)	10 U	—	0.2	0.3	—
	Bluegill	10 U	<0.2	0.2 U	0.2	0.4
	Largemouth Bass	—	—	—	0.7/0.2 U	0.2 U
	White Crappie	—	—	0.2 U	0.2 U	<0.2
	Black Crappie	—	—	—	<0.2	<0.2
	Notropis sp. (shiner)	10 U	—	—	—	—
	Pumpkinseed	—	0.2 U	—	—	–
	Turtle (muscle only)	—	—	0.2 U/0.3	—	—
	Turtle (liver only)	—	0.5	0.2 U/0.3	—	—
Control Site 1 Beaver Pond	Creek chubsucker	10 U	—	0.2 U	—	—
	Notropis sp. (shiner)	10 U	0.3	0.4	—	—
	Pumpkinseed	10 U	<0.2	—	—	–
	Largemouth bass	10 U	—	<0.2	—	—
Control Site 2 Mattawoman Creek	Creek Chubsucker	10 U	—	0.2 U	—	—
	Brown Bullhead	—	0.3	<0.2	—	—
	Pumpkinseed	10 U	0.3	—	—	—
	Bluegill	10 U	0.2 U	0.2 U	—	—
	Warmouth	—	—	0.2 U	—	—
	Largemouth bass	—	—	0.2 U	—	—

— Sample not collected
U Nondetect level shown is detection limit.

3.2 COMPARISON OF LEAD LEVELS

Lead levels in Site 56 fish appeared to be somewhat lower in November 1995 than August 1995 (Table 3-2). Seven of 10 fish samples collected in August 1995 contained measurable quantities of lead; 5 of 10 fish samples collected in November contained measurable concentrations. In August, the highest concentration of lead (1.6 mg/kg) was found in a large gizzard shad. It was suggested at that time that this value could be an anomaly or sampling artifact because it was a one-fish sample. However, a sample of six gizzard shad collected in November contained 0.7 mg/kg of lead, the second highest concentration recorded. The gizzard shad is generally regarded as a cruising planktivore that feeds on phyto- and zooplankton in open waters of large lakes and reservoirs. When confined to smaller, shallower bodies of water (like the Site 56 pond), gizzard shad are more likely to graze on or near the bottom on attached algae (Tomelleri and Eberle, 1990).

The state of Maryland performs fish tissue analysis for heavy metals as part of its Basic Water Monitoring Program (Maryland Department of Health and Mental Hygiene, 1986; Maryland Department of the Environment, 1988). Fish and crabs were collected from 31 stations across the state in 1983, 1984, and 1985. Lead concentrations in fish were based on whole-body analyses. Appendix A shows selected results of the 1983-1985 Maryland Department of the Environment Surveys of heavy metals in fish.

Data from the Basic Water Monitoring Program (Maryland Department of the Environment, 1988) indicate that lead levels in fish from Site 56 are typically lower than those observed in streams and rivers elsewhere in Maryland. Brown bullhead from the Lower Potomac River contained an average of 2.9 mg/kg in 1985, while brown bullhead from the Patuxent River contained 2.1 mg/kg. Bluegill from the Patuxent River contained 2.2 mg/kg in 1985. Pumpkinseed from the Choptank River contained 3.1 mg/kg in 1985. Redbreast collected in 1985 contained 2.6 mg/kg (Gunpowder River), 1.7 to 4.3 mg/kg (Patapsco River), 0.9 mg/kg (Lower Potomac River), and 1.3 to 2.8 mg/kg (Middle Potomac River). Fish from virtually every river and stream in Maryland sampled in 1985 contained higher levels of lead than fish in the Site 56 pond.

The U.S. Fish and Wildlife Service conducted a nationwide survey (1978-1981) of metals in fish as part of the National Contaminant Biomonitoring Program (Lowe et al., 1985). Whole-body concentrations of seven heavy metals, including lead, were determined for fish from 112 sampling stations. Appendix B shows lead concentrations in fish collected from sampling stations in Connecticut, New York, Pennsylvania, Maryland, and Virginia.

Lowe et al. (1985) report a national mean lead concentration in fish (all species, all locations) of 0.19 ppm for the 1978-1979 period and 0.17 ppm for the 1980-1981 period. These two means were not statistically

different. In fact, during the period from 1978-1979 to 1980-1981, the number of stations at which lead concentrations increased, exceeded the number of stations at which concentrations decreased.

The U.S. Fish and Wildlife Service surveys indicated that in bodies of water contaminated with lead, species that feed or scavenge near the bottom (e.g., catfish, carp, and goldfish) were more likely to contain high body burdens of lead than those that normally feed in open water or near the surface (largemouth bass and yellow perch). This pattern was most evident in fish from the Hudson River, where goldfish contained 1.12 to 1.90 ppm lead, and largemouth bass contained only 0.10 ppm. The U.S. Fish and Wildlife Service surveys also suggested that in relatively uncontaminated bodies of water, bottom feeders and scavengers did not show a pronounced tendency to accumulate lead. For example, redhorse suckers (*Moxostoma* sp.) and bass in the Potomac River at Little Falls, Maryland both contained 0.10 to 0.12 ppm lead.

Based on the August and November 1995 rounds of biomonitoring, concentrations of lead in whole-body samples of Site 56 fish are comparable to those reported by the U.S. Fish and Wildlife Service for fish from rivers in New York, Maryland, and Virginia (Lowe et al., 1985). Lead levels in Site 56 fish are consistently lower than those reported by the State of Maryland for fish from five rivers (the Potomac, Choptank, Gunpowder, Patapsco, and Patuxent) in the eastern part of the state (Maryland DHMH, 1986; Maryland DER, 1988).

The lead levels observed in fish tissue at Site 56 do not appear to represent a threat to piscivorous birds and mammals. Dietary concentrations of up to 8.4 and 7.3 mg/kg (as lead acetate) are not believed to be harmful to the great blue heron (*Ardea herodias*) and belted kingfisher (*Ceryle alcyon*), respectively (Opresko et al., 1994). Both of these species are largely piscivorous and both are year-round inhabitants of southern Maryland (Amos and Amos, 1987; Robbins et al., 1966). Although ingestion of food (such as fish) containing lead can exacerbate an existing body burden of lead in piscivorous birds, it is unlikely to cause clinical signs of lead poisoning in healthy, uncontaminated animals (Eisler, 1988).

Although there is a wealth of information in the scientific literature on the effects of ingested lead on humans, domestic animals (dogs and cats), laboratory animals (mice, rats, and monkeys), and farm animals (pigs, goats, and cows), there is little useful data on the toxic and sublethal effects of lead on mammalian wildlife (Eisler, 1988). Some investigators have attempted to characterize the effects of ingested lead on mammals in the wild by extrapolating from laboratory studies of small mammals. For example, Opresko et al. (1994) calculated that a concentration of up to 41.3 mg/kg in the diet as metallic lead was not harmful to mink (*Mustela vison*), basing this on laboratory studies of rats and correcting for anatomical, physiological, and behavioral differences between the two species. Mink, which feed on a variety of aquatic organisms (fish,

crayfish, and frogs), are found throughout southern Maryland (Burt, 1980; Whitaker, 1980) and probably use the Site 56 pond.

The fact that lead concentrations are elevated in Site 56 sediments and relatively low in Site 56 fish is not unusual, given lead's tendency to bind to sediments. Numerous studies have shown that lead in sediments is not readily bioavailable (Getz et al., 1977; Wiener and Giesy, 1979; Johnson, 1987). In a comprehensive study of lead dynamics in an Illinois watershed, Getz et al. (1977) found concentrations of lead in stream sediments that were two (a hundred times) to six (a million times) orders of magnitude higher than concentrations in benthic macroinvertebrates and fish. Demayo et al. (1982) found sediment concentrations of lead in an Oklahoma pond from 206 to 529 ppm, while *Gambusia* from the same pond contained 11 ppm of lead.

Unlike mercury, lead does not biomagnify (Eisler, 1988). Lead concentrations in aquatic ecosystems are often higher in sediments than in benthic macroinvertebrates, and higher in benthic macroinvertebrates than in surface-feeding or pelagic fish (Van Hassel et al., 1980; Eisler, 1988). Getz et al. (1977) noted that lead concentrations in aquatic organisms appear to be influenced by the amount of contact an organism has with contaminated sediments. Lead tends to concentrate in the bony tissues of individual fish, particularly species that forage on the bottom, and to accumulate in these tissues over time. Thus, older individuals may be at risk in a contaminated stream or lake, and in particular bottom-feeding groups such as bullheads, carpsuckers, and redhorse.

These limited data provide no evidence that lead contamination at Site 56 has moved into the food chain to a significant extent.

3.3 SUMMARY OF PREVIOUS INVESTIGATIONS

Composite fish and individual turtle samples from the October 1993, and April and October 1994 rounds of biomonitoring were split and analyzed for both mercury and lead residues. Results of lead analyses are presented in Table 3-2. As shown on that table, during the first three rounds of biomonitoring, samples were also collected from two nearby control sites that did not have elevated levels of lead in the sediments. Also, the analytical method used to analyze for lead was changed between the October 1993 and April 1994 rounds to take advantage of a lower detection limit. As shown on Table 3-2, the detection limit was significantly lower between the October 1993 round (10 mg/kg) and the subsequent rounds (0.2 mg/kg).

No clear-cut patterns of lead accumulation in fish emerged from these preliminary investigations. In April 1994, no fish taken from the Site 56 pond contained measurable (>0.2 mg/kg) levels of lead, whereas fish

from both control sites contained measurable levels. Although bottom-feeding and bottom-dwelling species are more likely to accumulate significant body burdens of lead as a result of lead's tendency to bind to bottom sediment (Van Hassel et al., 1980; Eisler, 1988), no such pattern was observed in April 1994. Sample sizes were probably too small to detect any such tendencies, however. A sample of carp (two small fish) from the Site 56 pond in April 1994 contained low, but detectable (<0.2 mg/kg) concentrations of lead. A brown bullhead sample (one small fish) from the Mattawoman Creek control site contained a low, but measurable (0.3 mg/kg) concentration of lead. Both species are omnivorous bottom feeders (Scott and Crossman, 1973).

Notropid minnows (unidentified shiners) from the beaver pond control site also contained low, but measurable, concentrations of lead in April 1994 as did a pumpkinseed (one fish) from Mattawoman Creek. Notropid food habits vary with the species and the size/age of individual fish. Notropids feed on plant material, plankton, and both larval and adult insects (Tomelleri and Eberle, 1990). Some species feed on the bottom, while others feed primarily at the surface (Scott and Crossman, 1973). Pumpkinseed are opportunistic omnivores that feed at the surface, at various depths in the water column, and at the bottom (Scott and Crossman, 1973).

Lead levels in October 1994 fish samples from the Site 56 pond were also generally low. One species, brown bullhead, contained lead concentrations that appeared to be higher than background levels. Lead concentrations in three other fish species were at or below the 0.2 mg/kg analytical quantitation limit for lead. Measurable concentrations (0.4 mg/kg) of lead were also present in Notropid (shiner) minnows from Control Site 1 (Stump Neck beaver pond).

In April 1994, lead concentrations in liver tissue from two painted turtles from the Site 56 pond averaged 0.5 mg/kg. In October 1994, liver and muscle tissue from one turtle contained a measurable concentration of lead (0.3 mg/kg), while liver and muscle tissue from another turtle did not contain a detectable quantity. Because almost no information on lead residues in reptiles is available, the significance of this data is difficult to assess. Eisler (1988) lists only one investigation of lead levels in turtles, but the species studied (the eastern box turtle, *Terrapene carolina*), is a largely terrestrial species, while the painted turtle is semi-aquatic. Perhaps more importantly, in terms of comparing body burdens of metals, the eastern box turtle is an unusually long-lived turtle species: 30- to 40-year-old individuals are common, and they may live as long as 100 years (Conant, 1975). Lead concentrations in a 17-year-old box turtle from an uncontaminated site in West Virginia were 4.0 mg/kg (long bones), 2.0 mg/kg (kidney), 1.0 mg/kg (liver), and 0.1 mg/kg (skin) (Eisler, 1988). Based on this study (and other studies of snakes, frogs, and toads in the same reference), the lead concentrations in livers of painted turtles from Site 56 appear to be unremarkable.

4.0 CONCLUSIONS

Although lead levels in sediments of the Site 56 pond are elevated, body burdens of lead in resident fish are not markedly elevated. The levels of lead in the fish from Site 56 are generally comparable to those in fish from a variety of aquatic habitats in the eastern U.S. Lead concentrations in Site 56 fish tend to be higher in fish species (brown bullhead and gizzard shad) that forage or scavenge on the bottom, than in fish species that feed in the water column or at the surface. There are no clear-cut differences with respect to trophic level: carnivores are no more likely to accumulate lead than herbivores or omnivores.

The data suggest that lead in sediments at Site 56 may be in a form that is not readily bioavailable and that Site 56 biota are not accumulating lead to a significant degree. There is no evidence of food chain biomagnification and no evidence to suggest that fish at Site 56 have been significantly affected by elevated levels of lead in the sediments.

REFERENCES

Amos, W. H., and S. H. Amos. 1987. Atlantic & Gulf Coasts (Second Printing). Alfred A. Knopf, New York.

Burt, W. H. 1980. A Field Guide to the Mammals (Third Edition). Houghton-Mifflin Company, Boston, Massachusetts.

Carlander, K. D., 1977. Handbook of Freshwater Fishery Biology: Volume Two. Iowa State University Press, Ames, Iowa.

Conant, R. 1975. A Field Guide to Reptiles and Amphibians of Eastern/Central North America. Houghton-Mifflin, Boston, Massachusetts.

Demayo, A., M.C. Taylor, K. W. Taylor, and P. V. Hodson. 1982. Toxic effects of lead and lead compounds on human health, aquatic life, wildlife plants, and livestock. CRC Crit. Rev. Environ. Control 12:257-305.

Eisler, R. 1988. Lead Hazards to Fish, Wildlife, and Invertebrates: A Synoptic Review. U.S. Fish and Wildlife Service, Biological Report 85(1.14).

Getz, L. L., A. W. Haney, R. W. Larimore, J. W. McNurney, H. V. Leland, P. W. Price, G. L. Rolfe, R. L. Wortman, J. L. Hudson, R. L. Solomon, and K. A. Reinbold. 1977. "Transport and Distribution in a Watershed Ecosystem" in W. R. Boggess and B. G. Wixson (Eds), Lead in the Environment. National Science Foundation, Washington, D.C. NSF/RA-770214.

Halliburton NUS Corporation (Halliburton NUS). 1993. Report on October 1993 Biomonitoring for Site 8 - Nitroglycerin Plant Office: Indian Head Division, Naval Surface Warfare Center, Indian Head, Maryland.

Halliburton NUS Corporation (Halliburton NUS). 1994. Report on April 1994b Biomonitoring for Site 8 - Nitroglycerin Plant Office: Indian Head Division, Naval Surface Warfare Center, Indian Head, Maryland.

Halliburton NUS Corporation (Halliburton NUS). 1995a. Report on October 1994 Biomonitoring for Site 8 - Nitroglycerin Plant Office: Indian Head Division, Naval Surface Warfare Center, Indian Head, Maryland.

Halliburton NUS Environmental Corporation (Halliburton NUS). 1995b. Supplemental Biomonitoring Plan for Site 8 - Nitroglycerin Plan Office: Indian Head Division, Naval Surface Warfare Center, Indian Head, Maryland. Revision 2 (July 1995).

Johnson, M. G. 1987. Trace element loadings to sediments of fourteen Ontario lakes and correlations with concentrations in fish. Can. Journal Fish. Aquatic Sci. 44:3.

Lowe, T. P., T. W. May, W. G. Brumbaugh, and D. A. Kane. 1985. National contaminant biomonitoring program: concentrations of seven elements in freshwater fish, 1978-1981. Archives of Environmental Contamination and Toxicology 14:363-388.

Maryland Department of Health and Mental Hygiene (DHMH). 1986. Basic Water Monitoring Program: Fish Tissue Analysis - 1983 and 1984. State of Maryland, Office of Environmental Programs, Water Management Administration, Technical Report No. 44.

Maryland Department of the Environment (DER). 1988. Basic Water Monitoring Program: Fish Tissue Analysis-1985. State of Maryland, Department of the Environment, Water Management Administration, Technical Report No. 59.

Opresko, D. M., B. E. Sample, and G. W. Suter. 1994. Toxicological Benchmarks for Wildlife: 1994 Revision. ES/ER/TM-86/RI. Oak Ridge National Laboratory, Oak Ridge, Tennessee.

Robbins, C. S., B. Bruun, and H. S. Zim. 1966. Birds of North America. Golden Press, New York.

Rohde, F. C., R. G. Arndt, D. G. Lindquist, and J. F. Parnell. 1994. Freshwater Fishes of the Carolinas, Virginia, Maryland, and Delaware. University of North Carolina Press, Chapel Hill, North Carolina.

Scott, W. B., and E. J. Crossman. 1973. Freshwater Fishes of Canada (Bulletin 184). Fisheries Research Board of Canada, Ottawa, Ontario, Canada.

Sorensen, E. M. 1991. Metal Poisoning in Fish. CRC Press, Boca Raton, Florida.

Tomelleri, J. R., and M. E. Eberle. 1990. Fishes of the Central United States. University Press of Kansas, Lawrence, Kansas.

Van Hassel, J. H., J. J. Ney, and D. L. Garling. 1980. Heavy Metals in a Stream Ecosystem at Sites Near Highways. Transactions of the American Fisheries Society 109:636-643.

Whitaker, J. O. 1980. The Audubon Society Field Guide to North American Mammals. Alfred A. Knopf, New York.

Wiener, J. G., and J. P. Giesy. 1979. Concentrations of Cd, Cu, Mn, Pb, and Zn in fishes in a highly organic soft water pond. Journal Fish. Res. Bd. Canada: 36: 270.

APPENDIX A

LEAD LEVELS IN MARYLAND FISH

1983 - 1985

MARYLAND DEPARTMENT OF THE ENVIRONMENT
BASIC WATER MONITORING PROGRAM
WHOLE BODY FISH TISSUE ANALYSIS 1983-1985

Species	Location	Sample Size	Lead concentration (ppm)	Source
Sunfish (redbreast)	Choptank R.	5	2.2	1983 Study
	Gunpowder R.	6	3.6	1983 Study
	Middle Potomac R.	5	3.4	1983 Study
	Middle Potomac R.	6	3.8	1983 Study
	Patapsco R.	6	3.1	1983 Study
	Patapsco R.	6	3.6	1983 Study
	Patapsco R.	4	2.2	1983 Study
	Upper Potomac R.	5	3.1	1983 Study
	Washington Metropolitan Area	8	4.2	1983 Study
	Middle Potomac R.	8	0.9	1984 Study
	Middle Potomac R.	6	1.3	1984 Study
	Middle Potomac R.	7	3.8	1984 Study
	Patapsco R.	6	3.5	1984 Study
	Patapsco R.	7	2.1	1984 Study
	Patuxent R.	5	4.2	1984 Study
	Washington Metropolitan Area	8	1.4	1984 Study
	Gundpowder R.	6	2.6	1985 Study
	Patapsco R.	8	2.1	1985 Study
	Patapsco R.	4	1.7	1985 Study
	Patapsco R.	7	4.3	1985 Study
	Washington Metropolitan Area	8	0.9	1985 Study
	Middle Potomac R.	4	2.0	1985 Study
	Middle Potomac R.	5	1.3	1985 Study
	Middle Potomac R.	9	1.7	1985 Study
	Middle Potomac R.	7	2.8	1985 Study

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(Continued)

Species	Location	Sample Size	Lead concentration (ppm)	Source
Bluegill	Choptank R.	6	3.3	1983 Study
	Patuxent R.	5	1.7	1983 Study
	Choptank R.	6	1.6	1984 Study
	Patuxent R.	5	3.3	1984 Study
	Patuxent R.	5	2.2	1985 Study
Black Crappie	Middle Potomac R.	2	2.9	1983 Study
	Patuxent R.	7	2.7	1984 Study
	Patuxent R.	5	2.0	1985 Study
Pumpkinseed	Patapsco R.	9	2.9	1983 Study
	Patuxent R.	9	3.0	1983 Study
	Choptank R.	6	3.1	1985 Study
	Patuxent R.	.	1.6	1985 Study
Brown Bullhead	Patuxent R.	5	2.2	1983 Study
	Lower Potomac R.	1	4.8	1984 Study
	Lower Potomac R.	5	2.5	1984 Study
	Patuxent R.	3	3.1	1984 Study
	Patuxent R.	5	2.1	1985 Study
	Lower Potomac R.	10	2.9	1985 Study

APPENDIX B

LEAD LEVELS IN FISH FROM EASTERN U.S.

1978 - 1981

U.S. FISH AND WILDLIFE SERVICE
THE NATIONAL CONTAMINANT BIOMONITORING PROGRAM
WHOLE BODY LEAD CONCENTRATIONS IN FRESHWATER FISH

Species	Location	Date	Lead Concentration (ppm)
White catfish	Connecticut R. at Windsor Locks, CT	1978	1.02
White catfish	Connecticut R. at Windsor Locks, CT	1978	1.17
Yellow perch	Connecticut R. at Windsor Locks, CT	1978	0.57
White catfish	Connecticut R. at Windsor Locks, CT	1980	1.72
White catfish	Connecticut R. at Windsor Locks, CT	1980	1.94
Yellow perch	Connecticut R. at Windsor Locks, CT	1980	0.47
Goldfish	Hudson R. at Poughkeepsie, NY	1978	1.90
Goldfish	Hudson R. at Poughkeepsie, NY	1978	1.63
Largemouth bass	Hudson R. at Poughkeepsie, NY	1978	0.10
Goldfish	Hudson R. at Poughkeepsie, NY	1980	1.12
Largemouth bass	Hudson R. at Poughkeepsie, NY	1980	0.10
White perch	Delaware R. at Trenton, NY - Yardley, PA	1979	0.57
White sucker	Delaware R. at Trenton, NY - Yardley, PA	1979	0.37
White sucker	Delaware R. at Trenton, NY - Yardley, PA	1979	0.19
Largemouth bass	Delaware R. at Trenton, NY - Yardley, PA	1981	0.10
White sucker	Delaware R. at Trenton, NY - Yardley, PA	1981	0.36
White sucker	Delaware R. at Trenton, NY - Yardley, PA	1981	0.35
Common carp	Susquehanna R. at Conowingo Dam, MD	1979	0.10
Common carp	Susquehanna R. at Conowingo Dam, MD	1979	0.31
White perch	Susquehanna R. at Conowingo Dam, MD	1979	0.20
Common carp	Susquehanna R. at Conowingo Dam, MD	1981	0.26
Common carp	Susquehanna R. at Conowingo Dam, MD	1981	0.17

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WHOLE BODY LEAD CONCENTRATIONS IN FRESHWATER FISH
(Continued)

Species	Location	Date	Lead Concentration (ppm)
White perch	Susquehanna R. at Conowingo Dam, MD	1981	0.22
Common carp	Potomac R. at Little Falls, MD - McLean, VA	1979	0.16
Common carp	Potomac R. at Little Falls, MD - McLean, VA	1979	0.17
Smallmouth bass	Potomac R. at Little Falls, MD - McLean, VA	1979	0.10
Largemouth bass	Potomac R. at Little Falls, MD - McLean, VA	1981	0.10
Unident. Redhorse sp.	Potomac R. at Little Falls, MD - McLean, VA	1981	0.12
Unident. Redhorse sp.	Potomac R. at Little Falls, MD - McLean, VA	1981	0.12