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Mercury in Fish Collected Upstream and Downstream of Los Alamos National Laboratory, New Mexico: 1991–2004

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ABSTRACT

Small amounts of mercury (Hg) may exist in some canyon drainage systems within Los Alamos National Laboratory lands as a result of past discharges of untreated effluents. This paper reports on the concentrations of Hg in muscle (fillets) of various types of fish species collected downstream of LANL's influence from 1991 through 2004. The mean Hg concentration in fish from Cochiti reservoir (0.22 µg/g wet weight), which is located downstream of LANL, was similar to fish collected from a reservoir upstream of LANL (Abiquiu) (0.26 µg/g wet weight). Mercury concentrations in fish collected from both reservoirs exhibited significantly (Abiquiu = $p<0.05$ and Cochiti = $p<0.10$) decreasing trends over time. Predator fish like the northern pike (*Esox lucius*) contained significantly higher concentrations of Hg (0.39 µg/g wet weight) than bottom-feeding fish like the white sucker (*Catostomus commersoni*) (0.10 µg/g wet weight).

I. INTRODUCTION

During the early years of Los Alamos National Laboratory (LANL) operations, some canyon drainage systems, which are major pathways for contaminants to reach off-site receptors, received various amounts of untreated waste effluents (Purtymun, 1974; Hakonson et al., 1980; Fresquez et al., 1995; Bennett et al., 1996). As a result, some of these canyons contain small amounts of light, heavy, and nonmetal trace elements, including mercury (Hg) (Hakonson et al., 1980). Although most of the runoff and/or effluent flow in the canyons are lost to the underlying alluvium and to evapotranspiration before leaving LANL lands (Stephens et al., 1993), some flow from excessive storm events may reach the Rio Grande (RG) (Abeele et al., 1981). The RG is the main tributary in New Mexico (NM) and traverses approximately 750 river miles from its headwaters in the San Juan Mountains in southwestern Colorado, through the State of NM, to El Paso, Texas, and beyond to the Gulf of Mexico (Ellis et al., 1993).

Mercury concentrations in fish occurring in rivers, lakes, and reservoirs in NM have been of significant concern to the public for a number of years (Torres, 1998); there are currently 26 fish advisories for Hg in NM waters based on the 1 ppm (µg/g) wet weight (w w) Food and Drug Administration (FDA) action limit (NMDH, 1993). The main source of Hg into water systems is from atmospheric deposition resulting from natural degassing of the earth's crust (2,700 to 6,000 tons of Hg annually) and burning of fossil fuels (2,000 to 3,000 tons of Hg annually) (Foulke, 1994). Although the concentration of Hg in all but a few small, often ephemeral, rivers and streams in NM are very low (NMED 1999), inorganic Hg existing in the water is converted to methyl mercury—$(CH_3)Hg^+$, a neurotoxin—under anaerobic conditions by sulfate reducing bacteria (Driscoll et al., 1994; Bunce, 1991). Methyl mercury is fat and water soluble, which is easily taken up by living cells (Hammond and Foulkes, 1986); it is the main form of Hg in fish (95%) (Driscoll et al., 1994); and it bioaccumulates (e.g., larger fish > smaller fish) (Bache et al., 1971) and biomagnifies (e.g., carnivorous fish > omnivorous fish > herbivorous fish) readily (Ochiai, 1995).

As part of the environmental surveillance program at LANL, fish have been collected on an annual basis upstream and downstream of LANL to determine if there are any contaminants arising in these important resources as a result of Laboratory operations (Fresquez et al., 1994, 1999a, 1999b; Gonzales et al., 1999). The purpose of this paper is to report the concentrations of Hg in muscle (fillet) tissues of various fish species and trophic levels collected at Abiquiu reservoir (AR), which is upstream of LANL, and at Cochiti reservoir (CR), which is downstream of LANL, from 1991 through 2004.

II. MATERIALS AND METHODS

Fish were collected using gill nets from AR, a 4,290-acre impoundment located on the Rio Chama approximately 40 miles upstream of LANL, and CR, an 11,000-acre flood and sediment control project located on the Rio Grande approximately eight miles downstream of LANL from 1991 through 2003. All fish were placed into large plastic bags following collection, marked for identification, and transferred to LANL in an ice chest cooled to 4°C. In the laboratory, a subsample (~25 g wet) of muscle (fillet) from each fish was placed into a quart size Ziploc® plastic bag and submitted to an analytical laboratory for analysis of Hg. In 1991, samples were analyzed by the New Mexico Scientific Laboratory Division, Santa Fe; from 1994 through 1999, samples were analyzed by an internal LANL laboratory; and, from 2000 through 2003, samples were analyzed by Paragon Analytics, Inc., Fort Collins, Colorado. All methods of Hg analyses in fish have been described previously (Fresquez et al., 1994; Fresquez et al., 1996). Results are reported in µg/g w w.

Variations in the mean trace element content in muscle between fish species (e.g., catfish versus carp, etc.), trophic level (e.g., predator fish versus bottom-feeding fish), and reservoirs (e.g., AR versus CR) were assessed using a Wilcoxon Rank Sum Test at the 0.05 (Gilbert, 1987). Trend analysis for Hg concentrations over the 13-year period was completed using a Mann-Kendal test at the 0.05 and 0.10 probability level.

III. RESULTS AND DISCUSSION

Mercury concentrations in fish (fillets) collected from AR and CR over the years ranged from 0.03 to 1 µg/g w w (Table 1). The highest Hg concentrations were detected in a catfish each from AR and CR in 1994. Based on the mean concentrations of Hg in fish over the years, pike contained the highest (0.39 µg/g w w) and white sucker contained the lowest (0.10 µg/g w w). The general order was as follows: northern pike (*Esox lucius*) > small mouth bass (*Micropterus dolomieu)* = crappie (*Pomoxis annularis)* > walleye (*Sander vitreus)* > trout (*Salmo trutta*) > catfish (*Ictalurus punctatus*) > carp (*Cyprinus carpio*) > white bass (*Morone chrysops)* > white sucker (*Catostomus commersoni*). Concentrations of Hg in catfish (0.24 µg/g w w) from this study were very similar to Hg levels in catfish collected from Conchas (averaged 0.25 µg/g w w) and Santa Rosa (ranged from 0.22 to 0.33 µg/g w w) lakes (Bousek, 1996; Torres, 1998). As a group and regardless of collection sites, Hg concentrations were significantly ($p < 0.05$) higher in predator fish (average = 0.29 µg/g w w) than in bottom-feeding fish (average = 0.22 µg/g w w). Because Hg normally biomagnifies up the food chain, carnivorous fish readily contain more Hg than omnivorous or herbivorous fish (Ochiai, 1995).

Table 1. Descriptive statistics of mercury (µg/g w w) in muscle (fillet) of fish collected from reservoirs upstream and downstream of LANL from 1991 through 2003.

Fish Species	N	Minimum	Maximum	Mean (SD)[1]
Carp	42	0.05	0.51	0.22 (0.11)a,d
Catfish	69	0.03	1.00	0.24 (0.18)a,b
Crappie	8	0.17	0.55	0.30 (0.13)a
Pike	7	0.14	0.76	0.39 (0.20)a
Small Mouth Bass	4	0.06	0.57	0.30 (0.22)a,c
Trout	4	0.04	0.33	0.25 (0.14)a,c,e
Walleye	9	0.13	0.42	0.27 (0.09)a
White Bass	6	0.12	0.23	0.19 (0.04)b,d,e
White Sucker	11	0.03	0.25	0.10 (0.06)c

[1]Means within the same column followed by the same lower case letter were not significantly different at the 0.05 probability levels using a nonparametric Wilcoxon Rank Sum test.

Mercury concentrations in fish from CR, downstream of LANL, were similar in concentration of Hg in fish collected upstream of LANL (AR) (Table 2). With some notable (individual) exceptions, mean concentrations of Hg in fish from both AR and CR were within Hg concentrations typical of fish from nonpolluted fresh water systems (Abernathy and Cumbie, 1977) and below the FDA's action limit of 1 µg Hg/g w w (Torres, 1998). Overall, mean Hg concentrations in fish collected from both reservoirs show significantly decreasing trends over time; AR ($p = 0.016$) was significant at the 0.05 probability level and CR ($p = 0.10$) was significant at the 0.10 probability level. It is not completely known why concentrations of Hg are decreasing in fish collected from AR and CR, but the reduction of emissions in coal-burning power plants and/or the reduction of carbon sources within the reservoirs may be but two of the reasons. Since the early 1980s, for example, coal burning power plants in the northwest corner of NM have been required to install benturi scrubbers and bag houses to capture particulates and reduce air emissions (Paul Martinez, personnel communication, Environmental Engineer Specialist, Air Quality Bureau, New Mexico Environment Department, September 22, 1999). A reduction in air emissions from regional sources employing pollution-control technologies that capture Hg was shown to be one of the principal factors in declining Hg levels over time observed in lakes in the Midwestern U.S. (Engstrom and Swain, 1997). Additionally, since the conversion of Hg to methyl mercury is primarily a biological process, it has been demonstrated that Hg concentrations in fish tissue rise significantly in impoundments that form behind new dams, and then gradually decline to an equilibrium level as the carbon provided by flooded vegetation is depleted (NMED, 1999).

Table 2. Mean (±std dev) mercury (µg/g w w) concentrations in muscle (fillet) of fish collected from reservoirs upstream and downstream of LANL from 1991 through 2003.

Year[1]	Abiquiu Reservoir	Cochiti Reservoir
1991	0.36 (0.09)a[1]	0.34 (0.13)a
1994	0.37 (0.28)a	0.28 (0.32)a
1995	0.34 (0.26)a	0.12 (0.04)a
1996	0.34 (0.10)a	0.21 (0.10)b
1997	0.16 (0.10)a	0.15 (0.10)a
1999	0.24 (0.12)a	0.14 (0.09)a
2000	0.10 (0.06)b	0.17 (0.12)a
2001	0.27 (0.07)a	0.27 (0.15)a
2002	0.20 (0.09)a	0.12 (0.07)b
2003	0.13 (0.07)a	0.15 (0.10)a
Mean of Means (±SD)	0.26 (0.16)A[2]	0.22 (0.16)A

[1]Means within the same row followed by the same lower case letter were not significantly different at the 0.05 probability levels using a nonparametric Wilcoxon Rank Sum test.
[2]Means within the same column followed by the same upper case letter were not significantly different at the 0.05 probability levels using a nonparametric Wilcoxon Rank Sum test. (Note: since the test statistic was 0.069 this relationship was significantly different at the 0.10 probability level.)

IV. CONCLUSIONS

Mercury concentrations in fish collected from CR appear to be mostly a result of either natural and/or anthropogenic sources other than LANL. Bioaccumulation and biomagnification factors were probably the main reasons that larger predator fish like pike contained significantly higher levels of Hg than smaller bottom-feeding fish like the white sucker. Concentrations of Hg in fish collected from both reservoirs showed decreasing trends over time.

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