Magnitude of Mercury Levels in Fish Muscle Tissue from South Carolina Waters

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Many of the world's great gastronomic materpieces are based on fish from both freshwater and saltwater. The danger for human health, due to fish consumption, has been very well recognized. A survey of mercury residues in freshwater fish was undertaken to see if the problem of the magnitude of mercury contamination was evident in the South Carolina Fishery. These investigations were initiated to determine mercury levels in fish from a variety of South Carolina Waters. Samples of fish from freshwater sources all over the state of South Carolina were collected during 1974 and 1975. The species composition of the collections generally reflects the fish populations of the water sampled. Mercury determinations were made on 100 samples of fish taken from 22 locations covering 46 South Carolina counties. Triplicate samples of fish tissues were analyzed using flameless atomic absorption procedures. Findings of this report are that magnitude of mercury levels of fish from Lake Jocassee and Edisto River have been found to be higher than other waterways surveyed. Mercury levels exceeding the U. S. Food and Drug Administration guideline of 0.5 ppm have been found in Brown Trout, Pike and Mudfish. Different patterns of mercury concentration occurred between different tissues. Larger fish contain higher concentration of mercury than do smaller fish of the same species.

A survey of mercury residues in freshwater fish was undertaken in July 1974. These investigations were initiated to determine mercury levels in fish from a variety of South Carolina waters. The survey was undertaken to see if the problem of the magnitude of mercury contamination was evident in the South Carolina Fishery. The danger for human health, due to fish consumption, has been very well recognized. The first known cases of human poisoning from fish contaminated with methylmercury were reported in Japan, on Minamata.[1,2] Samples of fish from freshwater sources all over the state of South Carolina were collected during the summers of 1974 and 1975. Mercury determinations were made on 100 samples of fish taken from 22 locations covering 46 South Carolina counties. The species composition of the collections generally reflects the fish populations of the waters sampled. Triplicate samples of fish tissue were analyzed using flameless atomic absorption procedures out-lined by Hatch and Ott.[3] The significant findings of this report are that magnitude of mercury levels of fish from Lake Jocassee and Edisto River have been found to be higher than other waterways surveyed. Mercury levels exceeding the U.S. Food and Drug Administration guideline of 0.5 ppm for muscle tissue have been found in Brown Trout, Pike and Mudfish. Different patterns of mercury concentration occurred between different tissues. Larger fish contain higher concentration of mercury than do smaller fish of the same speices as reported by Scott and Armstrong.[4]

Experimental

Sample Collection. Samples of fish from freshwater sources of lakes, rivers, streams and ponds all over the state of South Carolina were collected during the summers of 1974 and 1975. Lakes include Marion, Moultrie, Murray, Clark Hill, Keowee, Wateree, Jocassee, Greenwood, Hartwell, Wylie, Robinson, Secession, and Cherokee Falls and rivers include Edisto River and Savannah River.

The fish collected were Bluegill (*Lepomis macrochirus*), White Bass (*Roccus crysops*), Largemouth Bass (*Micropeterus salmoides*), Brown Trout (*Salmo trutta*), Channel Catfish (*Ictalurus Punctatus*), Pike (*Esox lucius*), Black Crappie (*Pomoxis nigromaculatus*), Redbreast (*Lepomis auritus*), Shad (*Alosa sapidissima*), Warmouth (*Lepomis gulosus*), Striped Bass (*Roccus saxatilis*), Mudfish (*Amia calva*), Jackfish (*Caranx hippos*), Shiner (*Notropis spp*), and Carp.

Wet Digestion. Fish tissue, 0.2 to 0.3g were weighed accurately and placed in the bottom of a clean dry Erlenmeyer flask which is closed with a polyethylene stopper. Samples were digested with 5 ml of 9M sulfuric acid and 1 ml of 5.6M nitric acid mixture. The sample flasks were incubated in a shaking water bath at 58°C until the tissue was completely dissolved giving a clear solution (50—60 min). Sample flasks were removed from the bath and allowed to cool in ice. Chemical oxidation of the samples were carried out by addition of 5 ml of 5% potassium permanganate slowly with swirling in each flask. Samples were kept overnight before analysis without apparent loss of mercury. Enough water was added to make the total volume approximately 125 ml. 1.5% Hydroxylamine hydrochloride solution, 5 ml, was added to reduce the excess permanganate. After 30 s, 5 ml of 10% Tin(II) chloride solution was added and immediately attached the flask to the aeration system.[5]

Mercury Determination by Atomic Absorption. Digests were analyzed using flameless atomic absorption spectrophotometry procedures outlined by Hatch and Ott[3] and Uthe *et al.*[5] as modified for use with a Perkin Elmer, Coleman MAS-50 mercury analyzer. Determination of mercury in fish tissue was measured in parts per million (ppm). The analytical error was $\pm 10\%$ at 0.1 ppm mercury level.

Results and Discussion

Mercury determinations were made on 100 samples taken from 22 locations covering 46 South Carolina counties. The species composition of the collections generally reflects the fish populations of the waters sampled. All South Carolina fish analyzed countained mercury. Mercury levels in fish averaged 0.13 ppm and ranged between 0.02 and 0.64 ppm.

Different species vary in mercury content and larger fish contain higher concentrations of mercury than do small fish of the same species taken from the same water. Pike, Mudfish, Brown Trout and Largemouth Bass showed higher mercury concentrations, while the pan-

Table 1. Magnitude of mercury levels in fish muscle tissue from various South Carolina waters

Station	Date	Species	Weight (g)	Mercury in wet weight (ppm)
Lake Secession	2/3/75	Striped bass	679	0.03
	2/3/75	Striped bass	657	0.03
	2/5/75	White bass	627	0.05
	2/5/75	White bass	463	0.12
	2/5/75	White bass	495	0.13
	2/17/75	White bass	873	0.11
	2/17/75	White bass	705	0.09
	2/17/75	Black crappie	703	0.09
	3/3/75	Shad	164	0.21
	3/3/75	Shad	179	0.19
	3/3/75	Shad	194	0.16
	3/5/75	White bass	536	0.11
	3/5/75	Black crappie	400	0.08
	3/5/75	Shad	219	0.10
	3/5/75	White catfish	258	0.07
	3/19/75	White bass	502	0.10
Lake Wylie	5/26/75	Bluegill	73	0.02
(4-Season fishing)	5/26/75	Bluegill	78	0.03
	5/26/75	Bluegill	61	0.03
	5/29/75	Redbreast	66	0.04
	5/29/75	Redbreast	49	0.04
	5/29/75	Redbreast	45	0.03
Lake Wateree	6/4/75	Channel catfish	161	0.06
(Great Falls)	6/4/75	Channel catfish	131	0.03
	6/4/75	Channel catfish	95	0.02
Lake Robinson	5/19/75	Redbreast	253	0.05
(Near dam)	5/19/75	Bluegill	51	0.04
	5/19/75	Bluegill	40	0.04
	5/20/75	Bluegill	49	0.03
	5/20/75	Bluegill	42	0.04
	5/20/75	Bluegill	41	0.04
Lake Jocassee	5/21/75	Bluegill	17	0.02
(Boat dock)	10/13/75	Bluegill	117	0.31
	10/13/75	Bluegill	86	0.29
	10/13/75	Bluegill	86	0.18
	10/13/75	Bluegill	59	0.20
(Devil's fork)	2/9/76	Brown trout	1927	0.53
	2/19/76	Brown trout	1542	0.58
	2/19/75	Brown trout	2041	0.51
Lake Moultrile	7/18/74	Redbreast	25	0.16
(Monck's corner)	7/18/74	Bluegill	51	0.10
(Harry's fish camp)	9/30/75	Redbreast	106	0.14
	9/30/75	Redbreast	99	0.06
	9/30/75	Redbreast	76	0.08
	10/2/75	Bluegill	113	0.05
	10/2/75	Bluegill	93	0.04
	10/2/75	Bluegill	71	0.03
	10/6/75	Bass	54	0.08
	10/6/75	Bass	46	0.06
(Bonneau Dykes)	10/8/75	Channel catfish	172	0.06
	10/8/75	Channel catfish	113	0.04
Edisto River	7/18/74	Bluegill	29	0.48
(Orangeburg)	7/18/74	Warmouth	76	0.49
	1/22/75	Mudfish	2000	0.63
	1/22/75	Bass	53	0.45
	1/22/75	Warmouth	143	0.38
	7/15/75	Bluegill	29	0.36
	1/27/75	Largemouth bass	483	0.59
Lake Murray	7/25/74	Catfish	50	0.06
(Below dam)	7/25/74	Catfish	37	0.08
(Hendrix landing)	7/9/75	Pike	741	0.64
Lake Hartwell	9/16/74	Catfish	41	0.14
(Gulley)				
(Stone creek clove)	7/29/74	Bluegill	59	0.06
	7/29/74	Bass	52	0.07
	7/29/74	Bluegill	49	0.03
(Jewel Bridge)	10/16/75	Bluegill	112	0.14
	10/16/75	Bluegill	107	0.09
	10/16/75	Bluegill	102	0.09
	10/16/75	Bluegill	80	0.07
	10/22/75	Bluegill	79	0.08
	10/22/75	Bluegill	73	0.08
	10/22/75	Bluegill	70	0.06
	10/22/75	Bluegill	60	0.09
Lake Keowee	10/1/74	Bluegill	102	0.12
	10/1/74	Bluegill	86	0.08
	10/1/74	Bluegill	45	0.04
	9/24/74	Bluegill	41	0.08
Lake Marion	1/16/75	Bluegill	15	0.06
(Santee refuge)	1/16/75	Redbreast	33	0.06
	1/16/75	Jackfish	206	0.18
	1/20/75	Bass	352	0.09
	1/20/75	Shiner	39	0.03
Clark Hill reservoir	3/10/75	Redbreast	63	0.07
	3/10/75	Redbreast	42	0.04
	3/10/75	Redbreast	28	0.02
	3/10/75	Redbreast	23	0.02
Lake Greenwood	6/16/75	Bluegill	57	0.08
(Floyd's landing)	6/16/75	Bluegill	83	0.02
	6/16/75	Bluegill	58	0.02
Savannah River	2/19/75	Mudfish	972	0.17
	2/19/75	Catfish	188	0.09
	2/19/75	Catfish	140	0.06
(Cohan's bluff)	9/17/75	Redbreast	329	0.14
	9/17/75	Bluegill	82	0.06
	9/17/75	Redbreast	266	0.04
Cherokee Falls	10/27/75	Catfish	95	0.06
(Below dam)	10/27/75	Catfish	81	0.05
	10/27/75	Catfish	77	0.06
	10/27/75	Catfish	62	0.04
	10/29/75	Catfish	674	0.19

fishes, including Bluegill, Redbreast, Shad, Warmouth, Catfish, Carp, Shiner often showed low concentrations.

Mercury levels exceeding the U.S. Food and Drug Administration guideline of 0.5 ppm for flesh have been found in Pike, Trout and Mudfish. No fish weighing less than a thousand grams had mercury levels above the currently accepted guideline of 0.5 ppm. Of the three fish weighing more than a thousand grams whole body weight, a Pike (1.0 kg) had muscle mercury levels of 0.64 ppm; Mudfish (2.0 kg) had muscle mercury levels of 0.63 ppm and Brown Trout (1.9 kg) had muscle mercury levels of 0.53 ppm.

Concentrations increased with increased body weight and biological amplification or magnification of mercury occurred through the food chain. Mudfish feeds on the bottom sediments and that might be the reason for higher mercury content. Pike and Trout seem to have higher mercury levels because of their predatory (carnivorous) eating habits.

Mercury levels in fish samples taken from Lake Secession ranged from 0.03 to 0.21 ppm; Lake Wylie ranged form 0.02 to 0.04 ppm; Lake Wateree ranged from 0.02 to 0.06 ppm; Lake Robinson ranged from 0.03 to 0.05 ppm; Lake Jocassee ranged from 0.02 to 0.58 ppm; Lake Moultrie ranged from 0.03 to 0.16 ppm; Edisto River ranged from 0.36 to 0.63 ppm; Lake Murray ranged from 0.06 to 0.64 ppm; Lake Hartwell ranged from 0.03 to 0.14 ppm; Lake Keowee ranged from 0.04 to 0.12 ppm; Lake Marion ranged from 0.03 to 0.18 ppm; Lake Clark Hill ranged from 0.02 to 0.07 ppm; Lake Greenwood ranged from 0.02 to 0.08 ppm; Savannah River ranged from 0.06 to 0.17 ppm and Lake Cherokee Falls ranged from 0.04 to 0.19 ppm (Table 1).

Mercury levels in Bluegill taken from Lake Jocassee and Edisto River were about one order higher than all other lakes and rivers surveyed. Matsunaga[6] has reported that mercury levels in fish taken from rivers containing mercury of 0.02 μg/l were about one order higher than natural rivers containing mercury of 0.002 μg/l. Thus, the higher levels of mercury found in both Edisto River and Lake Jocassee Fish can be related to pollution due to exposure to waters from sewege, agricultural drainage, industry waste water, and surface pollutants.

In this study, mercury in waters and in sediments was also determined (Tables 2 and 3). The mercury levels of water from Lake Jocassee and Edisto River were higher than all other Lakes and Rivers.

Relative Mercury Content of Fish Tissues. The mercury levels in different tissues, liver, kidney, muscle, skin, bone, gills, scales, fin, gonads, brain, stomach, spleen and heart of Brown Trout were determined. It seems different patterns of mercury concentration occur between tissues (Fig. 1). This was concluded from the analysis of Brown Trout from Lake Jocassee. We selected this species as an ideal to find out patterns of mercury levels in different tissues, since it had more than 0.5 ppm mercury content which is the upper limit according to Food and Drug Administration guideline.

The mercury content of fin, eye, scales, skin, bone,

Table 2. Water qtality data

Sample station	pH	Mercury level (μg/l)
Lake Jocassee	6.3	0.025
Edisto River	6.5	0.026
Lake Wylie	6.8	<0.01
Lake Wateree	6.6	<0.01
Lake Robinson	6.5	<0.01
Lake Moultrie	6.9	<0.01
Lake Murray	6.7	<0.01
Lake Hartwell	6.5	<0.01
Lake Keowee	6.4	<0.01
Lake Marion	6.7	<0.01
Lake Clark Hill	6.6	<0.01
Lake Greenwood	6.7	<0.01
Savannah River	6.5	<0.01
Cherokee Falls	6.6	<0.01

Table 3. Sediment quality data

Sample station	Sediment type	Mercury level in dry weight (ppm)
Lake Jocassee	Coarse sand	0.07
Edisto River	Coarse sand	0.06
Lake Wylie	Fine sand	0.02
Lake Wateree	Fine sand	0.02
Lake Robinson	Fine sand	0.02
Lake Moultrie	Fine sand	0.01
Lake Murray	Fine sand	0.01
Lake Hartwell	Fine sand	0.03
Lake Keowee	Fine sand	0.03
Lake Marion	Fine sand	0.02
Lake Clark Hill	Fine sand	0.01
Lake Greenwood	Fine sand	0.02
Savannah River	Fine sand	0.03
Cherokee Falls	Fine sand	0.01

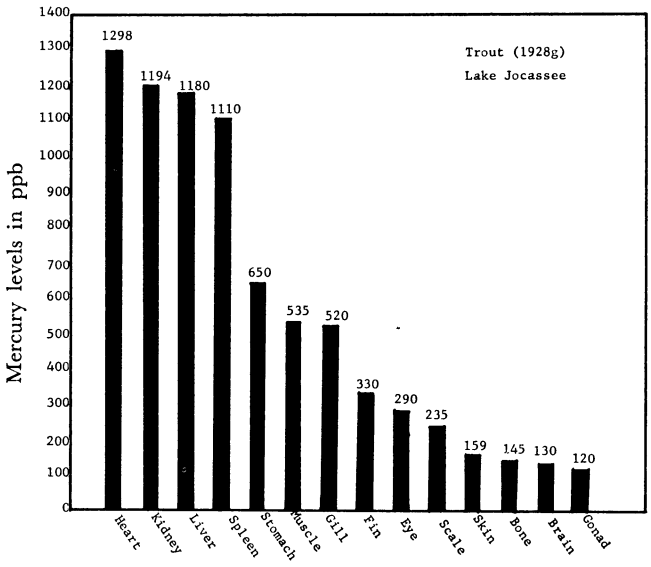

Fig. 1. Relative mercury content of fish tissues of Brown Trout.

brain and gonads was relatively low. Stomach, muscle and gills were intermediate in mercury content. Higher levels of mercury occurred in liver, kidney, spleen and heart (Fig. 1). It seems highly vascularized blood tissues had the highest mercury content than other tissues analyzed. The patterns of concentration occurred between tissues seemed characteristics of species, and suggests that patterns of uptake, accumulation and elimination differ between species.

Conclusions

The significant findings of this report are that magnitude of mercury levels of fish from Lake Jocassee and Edisto River have been found to be higher than other waterways surveyed. Carnivorous and bottom-feeding fishes are the most reliable indicators of mercury pollution. Mercury levels exceeding the U.S. Food and Drug Administration guideline of 0.5 ppm for muscle tissue have been found in Brown Trout, Pike and Mudfish. Different patterns of mercury concentration occurred between different tissues Larger fish contain higher concentration of mercury than do smaller fish of the same species.

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