Mercury Levels in Freshwater Fish of the State of South Carolina

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INTRODUCTION

By the end of this century, the waters of our world may be lifeless. Since the beginning of this century, contaminating waste dumped into our lakes, rivers and streams have increased 600%. Fish are dying.

The first known cases of human poisoning from fish contaminated with mercury were reported in Japan, on Minamata where 46 deaths and more than 121 cases of poisoning were reported (IRUKAYAMA, 1964 and KUTSUNA, 1968). The victims had eaten large quantities of fish and shellfish. In 1964 a similar outbreak of poisoning occurred at Niigata, Japan, where 43 cases including 6 deaths were officially documented (MINISTRY OF HEALTH, 1967).

In 1956 and 1960 outbreaks of mercurial poisoning involving hundreds of persons took place in Iraq, Pakistan and Guatemala where farmers ate grain seeds treated with mercurial fungicides instead of planting it (BAKIR et al. 1973).

In 1969, 41 million fish kills were found in North America. This fish kills were attributed to mercury pollution. They were ultimately traced to methylmercury contamination.

The vulnerability of freshwater habitats to mercury contamination was established by Swedish, Japanese and Canadian investigations. The fish feeding on small marine organism, on algae, and on sediments readily accumulate mercury to levels even 500 times higher than in comparable volumes of water. Practically all the mercury present in fish is in the form of methylmercury, CH_3Hg^+, which has been found to be readily absorbed by humans upon ingestion and is considerably more hazardous to humans (JENSON and JERNELOV, 1969 and WOOD et al. 1972). The retention time for methylmercury in fish is long, usually about 500 days half life, compared with humans 74 days half life (KECKES and MIETTENEN, 1970).

Metallic mercury is first converted into the organometallic compound, methylmercury. Biological methylation of mercury is accomplished by bacteria called Methanobacterium Omelanskii living in the bottom sediments (WOOD et al. 1968). These bacteria are then eaten by Zooplankton which in turn are eaten by fish.

Methylmercury is insidious poison and it enters human body through the algae-fish-human food chain. Methylmercury, a highly toxic substance that causes neurological damage, produces chromosomal aberrations, and has teratogenic effects (EYL, 1970).

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EXPERIMENTAL

Sample Collection

Samples of fish from freshwater sources of river, lakes, and ponds all over the state of South Carolina were collected during the Summer of 1974 and 1975. Lakes included Lake Marion, Moultrie, Murray, Clark Hill, Keowee, Wateree, Jocassee, Greenwood, Hartwell, Wylie and Robinson. The fish collected were Bass, Bluegill, Redbreast, Catfish, Shad, Carp, Crappie, Mudfish and Pike.

The whole fresh fish was frozen on ice in ice-chest and given an identification number, the date of collection, the place of collection and the weight. The fish was then transported to the laboratory for storage and analysis.

Wet Digestion

Fish tissue, 0.2g to 0.3g, were weighed accurately and placed in the bottom of a clean dry Erlenmeyer flask which is closed with polyethylene stopper. Samples were digested with 5 ml sulfuric acid and 1 ml nitric acid mixture. The sample flasks were incubated in a shaking water bath at 58°C until the tissue is completely dissolved giving a clear solution (50-60 minutes). 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 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. Hydroxylamine hydrochloride solution, 5 ml, was added to reduce the excess permanganate. After 30 seconds, 5 ml Stannous chloride solution was added and immediately attached the flask to the aeration system (UTHE et al. 1970).

Mercury Determination by Atomic Absorption

Digests were analyzed using flameless atomic absorption spectrophotometry procedure outlined by Hatch and Ott (HATCH and OTT, 1968), and Uthe et al (UTHE et al. 1970) as modified for use with a Perkin-Elmer, Coleman MAS-50 mercury analyzer. Flameless atomic absorption method for determination of mercury is sensitive and rapid by reason of the very high absorbance at 253.7 nm of mercury vapor, and the ready volatilization of the metal from acid reducing solution at room temperature. Hatch and Ott (1968) reduced mercury in acid solution by hydroxylamine hydrochloride/stannous chloride mixture and aerated the sample in a recirculation system. Air was passed through the reaction mixture, a drier, and the spectrophotometer cuvette back to the reaction flask. Absorbance of mercury vapor was increased to a constant value in three minutes. Determination of mercury in fish tissue was measured in parts per million (ppm) and was converted to parts per billion (ppb).

RESULTS and DISCUSSION

Relative Mercury Content of Muscle Tissue

Those species for which fish of widely differing weights were analyzed, larger fish had higher mercury levels (Table I). This relationship is evident for the muscle tissue of Bass, Bluegill, Shad, Catfish, Redbreast, Pike and Mudfish (Table I). The muscle mercury levels on a wet weight basis ranged from 20 ppb in Redbreast to 635 ppb in Pike fish with mean of 159.4 ppb for species analyzed (Table I).

TABLE I

Mercury Levels of the Muscle Tissue of Fish

Station/Place	Date	Species	Weight	Mercury In Flesh
Clark Hill	7/19/74	Redbreast	23 g	20 ppb
	7/19/74	Redbreast	28.5g	20 ppb
	7/19/74	Redbreast	42.2g	40 ppb
	7/19/74	Redbreast	63 g	73 ppb
Lake Secession	12/4/74	White Bass	627.2g	49 ppb
	12/4/74	White Bass	705.6g	90 ppb
	12/4/74	White Bass	873.3g	110 ppb
	12/4/74	Shad	164.4g	39 ppb
	12/4/74	Shad	179.2g	44 ppb
	12/4/74	Shad	219.1g	51 ppb
Lake Keowee	7/24/74	Bluegill	45.8g	40 ppb
	7/24/74	Bluegill	86.7g	80 ppb
	7/24/74	Bluegill	102.4g	120 ppb
Savannah River	7/15/74	Catfish	140.1g	60 ppb
	7/15/74	Catfish	188.4g	90 ppb
Lake Murray	6/19/75	Pike	1000 g	635 ppb
	7/19/74	Catfish	37 g	60 ppb
	7/19/74	Catfish	50.4g	80 ppb
Edisto River	8/8/74	Mudfish	2000 g	630 ppb
	6/24/74	Warmouth	76.7g	487 ppb
	8/8/74	Largemouth Bass	483.4g	530 ppb

The indication of positive weight - mercury content relationship in Shad, Bass, Bluegill, Catfish, Redbreast, Pike and Mudfish suggests that fish which take larger prey have higher dietary mercury levels - a major reason for the direct relationship of size with mercury levels. However, other factors such as age, metabolism, surface area and habitat are also important factors affecting the mercury levels in fish of different weights and species.

Mercury levels exceeding the U.S. Food and Drug Administration guideline of 500 ppb for flesh have been found in Pike and Mudfish. No fish weighing less than thousand grams had mercury levels above the currently accepted guideline of 500 ppb. Of two fish weighing more than thousand grams whole body weight of Pike fish (1000g) had muscle mercury levels of 635 ppb and Mudfish (2000g) had muscle mercury levels of 630 ppb exceeding the guideline of 500 ppb (Table I).

Concentrations increased with increased body weight and higher levels on the food chain. It seems bioamplification of mercury is up the food chain. Mudfish feeds on the bottom sediments and that might be the reason for higher mercury content. Pike seems to have higher mercury levels because of its predatory eating habit.

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 Pike and Mudfish were determined (Fig. 1 and 2). It seems different patterns of mercury concentration occur between tissues. This was concluded from the analyses of Mudfish from Edisto River and Pike fish from Lake Murray. We selected these two species as an ideal to find out patterns of mercury levels in different tissues, since they had more than 500 ppb mercury content which is the upper limit according to Food and Drug Administration guideline.

The mercury content of skin, bone, gills, scales and fin was relatively low in both species (Fig. 1 and 2). Gonads, brain, stomach, spleen and heart were intermediate in mercury content in both species (Fig. 1 and 2). Higher levels occurred in liver, kidney and muscle in both species (Fig. 1 and 2). The patterns of concentration occurred between tissues seemed characteristics of species, and suggests that patterns of uptake, accumulation and elimination differ between species. It seems highly vascularized blood tissues had the highest mercury content than other tissues analyzed (Fig. 1 and 2). Carnivorous (Predatory) and bottom-feeding fishes are the most reliable indicators of mercury pollution.

Calculations of muscle - liver ratios to Pike and Mudfish are presented in Table II. The ratio of muscle - liver is an indicator of "Mercury Cleaning" by fish, presumably due to rates of storage and excretion. As such, it could prove to be a reliable monitoring indicator of mercury contamination. The liver is apparently directly involved with the mercury cleaning process.

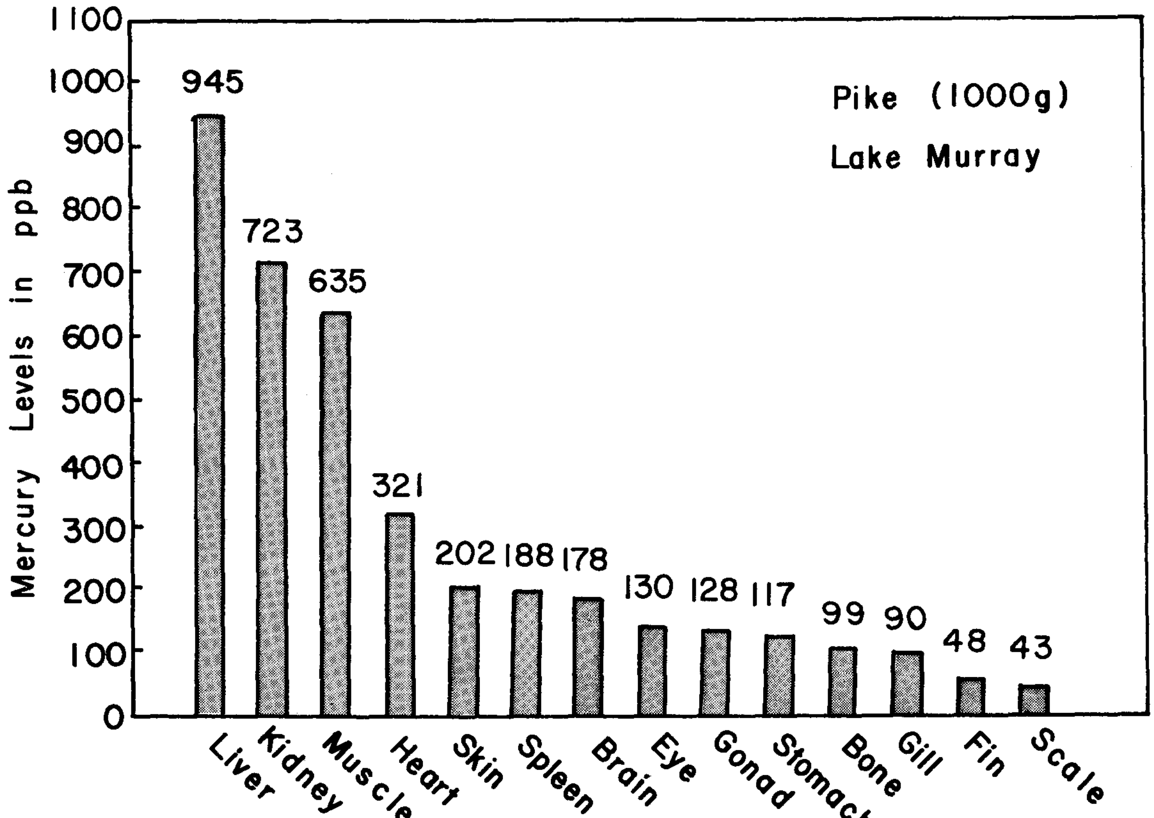

FIG. 1. Relative Mercury Content Of Fish Tissues

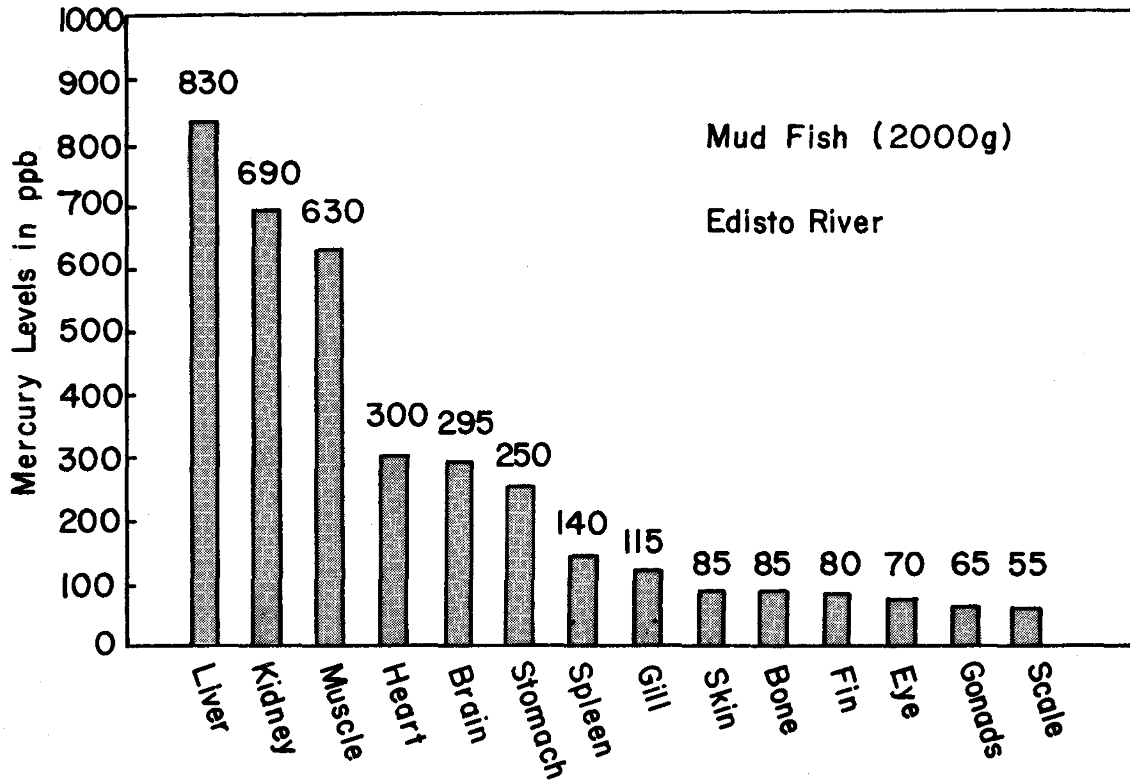

FIG. 2. Relative Mercury Content Of Fish Tissues

TABLE II

Muscle-Liver Ratios of Pike and Mudfish

Species Name	Mercury In Flesh	Mercury In Liver	Ratio Fraction	Ratio Decimal	Place
Pike	635 ppb	945 ppb	635/945	0.67	Lake Murray
Mudfish	630 ppb	830 ppb	630/830	0.76	Edisto River

Calculation of muscle - liver ratio from contaminated fish indicates that levels in the range of 0.5 preliminary indicative of environmental static conditions, whereas ratios in the range of 1.4 are indicative of environmental improvement.

SUMMARY

Samples of fish from freshwater sources of rivers, lakes and ponds all over the state of South Carolina were collected during the Summer of 1974 and 1975. The fish collected were Bass, Bluegill, Redbreast, Catfish, Shad, Carp, Crappie, Mudfish and Pike. Samples were analyzed using the flameless atomic absorption procedure outlined by Hatch and Ott, and Uthe et al as modified for use with Perkin-Elmer, Coleman MAS-50 mercury analyzer. Triplicate samples of fish tissue were analyzed by wet digestion method. The mean mercury levels in ppb were determined for baseline mercury levels. A significant finding of this report is that those species for which fish of widely differing weights were analyzed, larger fish had higher mercury levels. Mercury levels exceeding the U.S. Food and Drug Administration guideline of 500 ppb for fish tissues have been found in the Mudfish from Edisto River and Pike fish from Lake Murray. Higher levels of mercury occurred in the highly vascularized blood tissues of liver and kidney than in muscle. Carnivorous and bottom-feeding fishes are the most reliable indicators of mercury pollution.

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