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RETROSPECTIVE ASSESSMENT OF A POTENTIAL CADMIUM HAZARD[1]

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ABSTRACT. In 1968 an accidental discharge of cadmium plating solution caused a significant fish kill near Ravenna, Ohio. Water (130 samples) from West Branch Reservoir in 1971 and 1973 contained up to 0.055 mg/l cadmium, and fish (nine species, muscle tissue) contained up to 0.34 mg/kg. As a control, water and fish were sampled from Nimisila Reservoir. Cadmium was not detected in water (eight samples, 0.001 mg/l detection limit) and was detected in only one of eight species of fish (0.21 mg/kg).

There is a delicate balance of responsibility between concern for public health or safety and the need for conclusive data in assessing and announcing a potential hazard. Water samples from West Branch Reservoir exceeded the drinking water standard of 0.01 mg/l, but it was not used as a public source. All fish sampled from West Branch Reservoir contained measureable cadmium, but no standard had been set. Under these circumstances one could not clearly assess the hazard.

In 1979, the Environmental Protection Agency (EPA), in developing guidelines for application of sewage sludge to agricultural lands, concluded that 70 μg per day cadmium is a reasonable maximum dietary intake.

Was there an imminent hazard? Daily consumption of 227 g of fish (muscle tissue, average of seven species) would have resulted in an increase of 45 μg cadmium per day; 227 g of carp *(Cyprinus carpio)* (muscle tissue, highest value) in an increase of 77 μg cadmium per day. Added to the estimate of 39 μg per day dietary intake of cadmium, each situation exceeded the recently set 70 μg/day limit. Because the EPA standard is set low (allowing for the equivalent of 75 μg/day intake by heavy smokers plus 55 μg/day as a safety margin between the limit and the minimum at which damage occurs), the occasional consumption of fish would not have represented a major hazard.

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INTRODUCTION

A small fish kill was reported in April 1968, by the *Record-Courier,* a Kent-Ravenna, Ohio newspaper. This occurred at a point near where the west branch of the Mahoning River enters the reservoir (fig. 1). In July of that same year, there was a second fish kill, numbering approximately 34,700. An investigation by the State of Ohio, Division of Wildlife, revealed that Allen Aircraft Products, Inc. had accidentally spilled 285–380 l of concentrated plating solution into a sewer which empties into the Eastpark drainage ditch. Composition of the solution was reported: cadmium metal 18,000 mg/l, sodium cyanide 130,000 mg/l, and caustic soda 22,000 mg/l. This drainage ditch empties directly into the west branch of the Mahoning River (fig. 1) (State of Ohio, Div. of Wildlife 1972, pers. comm.). In June 1970, there was another, but smaller, fish kill which resulted in the loss of 246 fishes.

METHODS AND MATERIALS

Water samples were collected from pre-selected depths using a Foerst water sampler at two reservoirs. A one–liter cubitainer and cap were rinsed with a small amount of the sample and then filled. Air was expelled and the cubitainer was capped and

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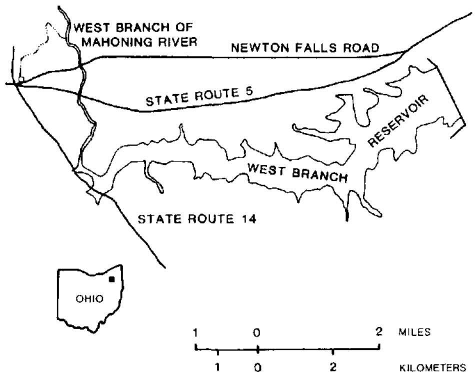

FIGURE 1. Location map showing path of spill from near intersection of Newton Falls Rd. and State Rts. 5 and 14 into West Branch Reservoir.

labeled with the depth and date. With the exception of gizzard shad (*Dorosoma cepedianum*), all fish were collected by common angling methods. Shad are herbacious in their eating habits and will not normally strike a baited hook. At West Branch Reservoir, this species was collected after the fish had been flushed through the dam, rendered unconscious, and had floated to the surface of the stream immediately below the dam. At the second reservoir, gizzard shad were collected by bow fishing. After capture, the fish were placed in plastic bags, labeled, and stored in a freezer which maintained the temperature at −10°C.

Methods of dissection, homogenization, ashing, and analysis are those used by the U.S. Department of the Interior, Wildlife and Fisheries Division (William Hesselberg, U.S. Dept. Of Interior, Wildlife and Fisheries Div. 1972, pers. comm.). A Perkin-Elmer Model 303 Atomic Absorption Spectrophotometer was used for the analysis of the unfiltered water and fish samples. Methods were the standard procedures as outlined by Perkin-Elmer (1971).

RESULTS

High amounts of certain trace elements (Manner 1971) were found in the water of West Branch Reservoir in fall and winter of 1970-1971, about 30 mo after the large spill. In some samples, three trace elements, cadmium, chromium, and nickel, exceeded the recommended limits set by the U.S. Public Health Service (USPHS) for potable water. Two other elements, zinc and copper, exceeded the amount generally found in natural waters. Table 1 summarizes our early results for trace elements in the waters of West Branch Reservoir. A slight decrease in cadmium content of water, ranging up to .017 mg/l with a mean of .009, just under the USPHS standard of .01 was found about 45 mo after the large spill.Cadmium content was not related to depth of water.

A summation of cadmium analyses is shown in fig. 2, including samples in the 0.45-2.80 mg/l range taken by others in the drainage ditch. Our analyses are shown at about 30 and 45 mo.

A second reservoir, with similar characteristics except for the plating spill, was investigated to find background levels of cadmium in water. Although smaller than West Branch Reservoir, Nimisila Reservoir has appropriate characteristics as shown in table 2.

West Branch Reservoir and Nimisila Reservoir are built over glacial till, have approximately the same fish species, and are used for low flow augmentation. Nei-

TABLE 1

Selected elements in West Branch Reservoir (after Manner 1971).

Element	Range (in mg/l)	Mean (in mg/l)	USPHS Stand.	Amt. in Excess USPHS Stand.
Cadmium	.012-.055	.03	.01	.02
Chromium	.039-.165	.08	.05	.03
Copper	.002-.050	.03	1.00	.00
Nickel	.030-.200	.09	.05	.04
Zinc	.005-.030	.02	5.00	.00

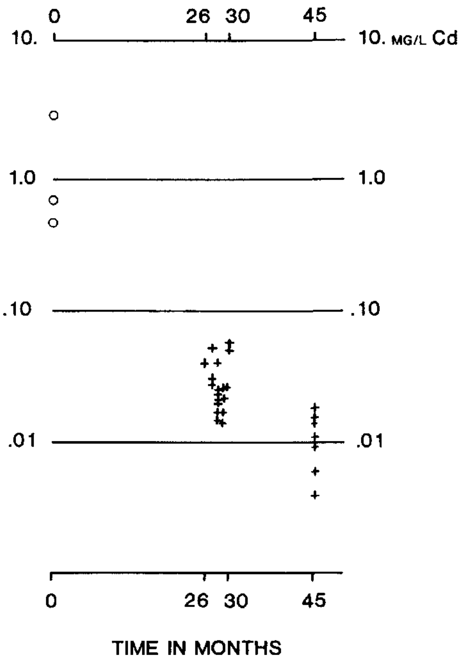

FIGURE 2. Cadmium in mg/l detected in drainage ditch (o) at time of spill, and in reservoir (+) at 25-30 mo and 45 mo after spill.

ther reservoir is used as a source of water for human consumption. West Branch Reservoir and drainage basin is considerably larger. West Branch Reservoir is much more widely used for recreational purposes. West Branch Reservoir receives treated waste material, whereas Nimisila Reservoir is almost completely free of waste material. West Branch Reservoir has three continuous sources of recharge, and Nimisila has only one main source, runoff. The area surrounding West Branch Reservoir is used for residential, industrial, and agricultural purposes, and the area surrounding Nimisila Reservoir is owned by the State of Ohio and is used as a buffer zone between the reservoir and the residential areas.

Analyses of water from Nimisila Reservoir indicated no cadmium (detection limit of .001 mg/l). Analyses of fish show that cadmium had accumulated in the food chain. In table 3, results of cadmium analyses for whole fish and for muscle tissue only are presented. With one exception of parity, whole fish and muscle tissue analyses were consistently higher by a factor of two or more in fish from West Branch Reservoir.

DISCUSSION

Because water from West Branch Reservoir was not a public water source, there was no defined hazard, even though the potable water quality limit for cadmium was exceeded.

The question of an imminent hazard with regard to fish as a source of human

TABLE 2

Comparison of West Branch and Nimisila Reservoirs.

Reservoir	Year Built	Type of Dam	Length of Dam (m)	Substrata	Hectares under water	Max. Stor Capacity (m^3)	Recharge Sources	Purpose	Drainage Basin (km^2)
West Branch Reservoir	1965	Rolled earth fill	3,018	Wisconsin age glacial till	1,072	97,100,000	West Br. Mahoning Creeks Runoff	Low Flow Augmen. Flood control Recrea.	207
Nimisila Reservoir	1937	Rolled earth fill	549	Wisconsin age glacial till	334	9,370,000	Runoff	Low flow Augmen. Limited Recrea.	49.3

TABLE 3

Inventory and cadmium content for species analyzed in mg/kg (Lee 1973).

Species	West Branch Reservoir		Nimisila Reservoir	
	Whole Fish	Muscle Tissue	Whole Fish	Muscle Tissue
Dorosoma cepedianum	0.35	0.20	<0.001	0.21
Pomoxis annularis	0.56	0.08	<0.001	<0.001
Ictalurus nebulosus	0.51	0.17	<0.001	<0.001
Cyprinus carpio	N.A.	0.34	N.A.	<0.001
Lepomis macrochirus	0.35	0.27	0.19	<0.001
Perca flavescens	0.31	0.16	<0.001	N.A.
Catostomus commersoni	N.A.	0.17	N.A.	N.A.
Ambloplitis rupestris	<0.001	N.A.	<0.001	N.A.
Micropterus salmoides	0.39	N.A.	<0.001	N.A.

food was not easily resolved. The only well known incident of cadmium poisoning at that time had been at Sasu River Basin in Japan. Itai-itai disease was manifested by the fracturing of the bones and skeletal deformation. Industrially-polluted waters had been used for irrigation, and eight vegetables had shown cadmium contents reported in a range of .14-.85 mg/kg, with a mean of .35 mg/kg. These vegetables constituted a major portion of the diet of those affected, resulting in a dietary intake of 300-600 μg/day. By comparison ingestion of dietary cadmium had been estimated at 50 μg per day in most countries, with a probable variation from 25 to 75 μg/day (Friberg et al. 1974).

At the time of the spill, no standards for cadmium involving commercial fish had been set in the U.S. The question of whether a hazard existed because of consumption of fish from West Branch Reservoir could not be resolved by comparison to the Sasu basin. Although our highest value for cadmium in fish muscle was .34 mg/kg and our average was .20 mg/kg, these fish were not a major portion of anyone's diet, weakening a comparison with the Sasu basin.

Was there an imminent hazard? Daily consumption of 227 g of fish (muscle tissue, average of seven species) would have resulted in an increase of 45 μg per day; 227 g of carp (muscle tissue, highest value) in an increase of 77 μg cadmium per day. On the basis of data available at that time, there was not sufficient evidence to consider the fish an imminent health hazard.

The Environmental Protection Agency (Federal Register 13 Sept. 1979) has addressed the policy question of dietary cadmium presented by land spreading of sewage sludge. Sewage sludge adds organic matter, nitrogen, phosphorus, and trace elements to the soil. As such, cadmium is increased in the soils and in the crops. EPA guidelines allow an increase of 30 μg/day dietary cadmium, from the 1977 FDA estimate of 39 μg/day for the American diet. High risk individuals, such as heavy smokers, still have a margin of 55 μg/day between the new dietary guideline plus additional amounts ingested by smoking three packs per day, and the minimum accepted value of 200 μg/per day for renal cortex damage from long term intake (Naylor and Loehr 1981). This approach and the model resulting from it have been questioned, however, because of individual biological variability. Intakes of from 80 to 100 μg/day may result in renal damage for 2.5 to 5.0% of the population by age 50 (USEPA 1979). As of this date, there has been no revision of the guidelines.

The current EPA model recognizes 200 μg/day cadmium ingestion as borderline for renal cortex damage after long term, (50 yr), and builds in a safety margin of 55 μg/day; manipulation of two variables allows a retrospective assessment of any health hazard from eating fish from

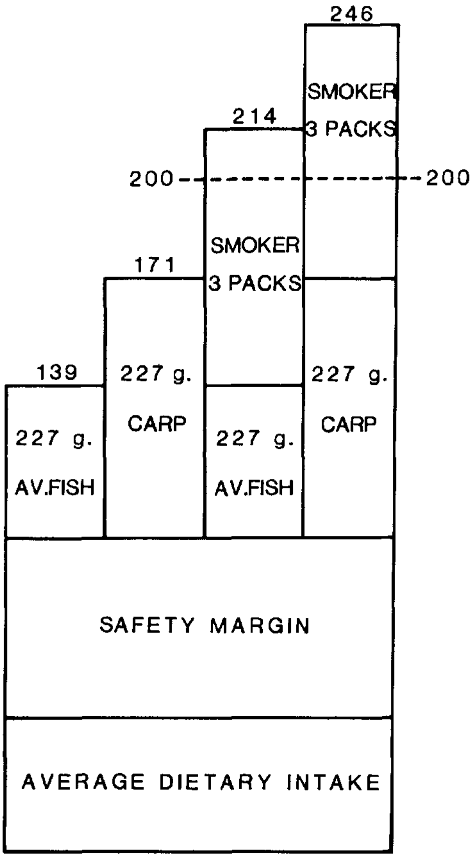

FIGURE 3. Bar chart showing estimated daily intake of cadmium in μg. Each situation incorporates FDA estimate of 39 μg dietary intake and safety margin of 55 μg. Other variables are consumption of 227 g fish with average cadmium content or 227 g fish with highest cadmium content, by non-smoker and "three-pack" smoker. Threshold for renal cortex damage is 200 μg/day.

West Branch Reservoir. The variables are the value chosen for cadmium in fish (45 μg average for all fish or 77 μg for carp) and whether the individual was a non-smoker or heavy smoker (equivalent to dietary intake of 75 μg/day cadmium from three packs). These factors are tabulated in fig. 3, and summarized in fig. 4.

The only person at risk would have been the heavy smoker, eating fish from West Branch Reservoir on a regular basis (two cases). The only person clearly not at risk is the non-smoker eating fish on a regular basis (two cases). Because fish from West Branch probably was not part of anyone's daily diet for an extended period of time, there was no imminent health hazard. However, in 1973, such an assessment, either way, could not have been made in the absence of a model or the establishment of standards based upon a model.

	NON-SMOKER	HEAVY SMOKER
CARP	171	246
AV. FISH	139	214

FIGURE 4. Summation of cadmium intake in μg/day for variables of consumption of fish and smoker, or non-smoker. Threshold for renal cortex damage is 200 μg/day. All situations include 39 μg/day dietary intake and 55 μg/day safety margin.

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