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Mercury in Freshwater Fish and Clams from the Cerro Prieto Geothermal Field of Baja California, México

Efraín A. Gutiérrez-Galindo, Gilberto Flores Muñoz, and Alejandro Aguilar Flores

Instituto de Investigaciones Oceanológicas, Universidad Autónoma de Baja California, P.O. Box 453, Ensenada, Baja California, México

Several reports have expressed concern about the potential toxicity hazards and environmental contamination of mercury emissions from geothermal fields in Hawaii New Zealand, Iceland, California and Mexico. Inorganic mercury discharged from these sources may accumulate in the sediments of rivers or lakes and, after microbiological methylation may become concentrated in the edible tissue of fish (Weissberg and Zobel 1973; Robertson et al. 1977).

In the agricultural Mexicali Valley, Baja California is located the Cerro Prieto geothermal field approximately 40 km south of the U.S.A. - Mexican border. The Cerro Prieto field is a hot water-dominated reservoir and has been in operation since 1973 with an initial supply of 75 Mwe. Studies have indicated that in 1973, maximum total mercury losses were up to 47 kg yr^{-1}, of which 90% were estimated as loss to the atmosphere and the remainder to water effluents (Mercado 1976). For 1987, this geothermal complex expect to supply 510 Mwe of electricity, which represent a great potential concern to the public health authority.

This study involves assessment of geothermal mercury pollution arising from Cerro Prieto. For this purpose the fish *Tilapia mossambica* and the clam *Corbicula fluminea* were collected from the freshwater courses of the Mexicali Valley. Reports (Est. Gen. B.C. 1983) indicated that in 1982, 13 t of

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Send reprint requests to E.A. Gutiérrez-Galindo at the above address.

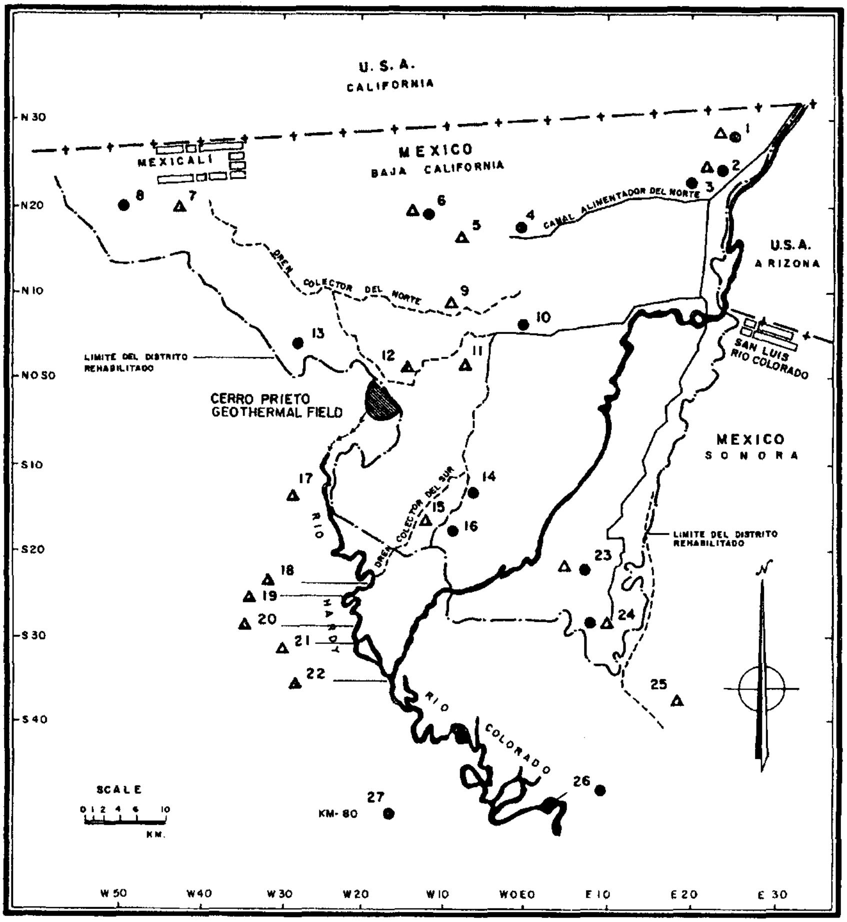

Figure 1. Map of the Mexicali Valley showing sampling sites of fish ▲ and clams ●

T. mossambica were destinated for human consumption. A further aim was to provide base line data and information relevant to the level of mercury contamination for the Mexicali Valley.

MATERIALS AND METHODS

Fish samples were collected in August 1985, February and June 1986 from the Mexicali Valley (Fig. 1). Clam samples were collected at the given Valley during February 1986. The samples were immediately frozen on dry ice. The muscle tissue on the lateral sides of a fish was removed with stainless steel scalpels and kept frozen at -20°C until analysis. Three subsamples of 25 clams at each site were prepared. The available literature on trace element variability within bivalve population (Boyden and Phillips 1981) suggests that a sample of twenty-five organisms is sufficient to characterise accurately the element concentrations present in a population. The procedures for mercury analysis are summarized in Stephenson et al. (1979). The dissection, homogenization and digestion (1 g wet material) of fish and clam tissue samples were in the trace metal clean laboratory at Instituto de Investigaciones Oceanologicas following the recommendations of Patterson and Settle (1975). Mercury was determined by cold-vapor atomic absorption spectrometry. Quality control of all analysis was ensured by the study of reference materials (S R M 1521 National Bureau of Standards, Washington, USA).

RESULTS AND DISCUSSION

The mean values for total mercury levels of the edible muscle tissue of fish *T. mossambica* and clam *C. fluminea* included in this study, are shown in Table 1. Data for fish and shell lengths, wet weights and dry weights are also included. The mean mercury levels ranged from 0.01 to 0.14 ug/g for fish and 0.01 to 0.32 ug/g for clam. Mercury concentrations are shown based on dry tissue weights in all cases. The equivalent data based on wet weight may be obtained using the wet weight/dry weight ratios.

Considering the different organisms analyzed, mercury concentrations were higher in clams than in the fishes. In clams the grand mean mercury concentration was 0.11 ug/g; in fishes the grand mean recorded was 0.05 ug/g (Table 1). The different tendencies of the two species to accumulate mercury in their bodies are probably associated with their feeding habitats as well as bioavailability of mercury in theirs habitats.

The results, indicate much higher concentrations of mercury in fishes living in water receiving considerable geothermal discharges (Rio Hardy) than in fishes living in similar waters receiving no geothermal discharges. It is possible that the Cerro Prieto effluent which is discharged into the Rio Hardy is the primary source of mercury pollution in the Mexicali Valley.

Analysis of variance showed that there were significant ($P < 0.05$) spatial differences in the concentration of mercury in fishes and clams from this study

Table 1. Mean values for length (cm), body weight (g) and mercury concentrations (ug/g dry weight) in the muscle tissue of edible fish *T. mossambica* and clam *C. fluminea*.

Date	Sampling site	n	Length	Wet weight	Dry weight	Hg
T. mossambica						
August 1985						
5	Canal Yucatán	3	18.0	53.2	6.71	0.02
9	Dren Jalapa	1	13.5	18.3	1.83	0.01
11	Dren Nuevo León	3	18.7	40.9	4.21	0.03
12	Dren Hidalgo	2	17.1	40.6	4.51	0.14
15	Dren Carranza	3	19.4	47.3	5.42	0.02
17	Canal Cucapah	3	14.63	21.7	2.34	0.07
21	Río Hardy	3	14.20	18.3	2.00	0.02
24	Canal Zacatecas	3	12.83	10.7	1.16	0.07
February 1986						
1	Canal Campillo	1	27.0	154.7	1.19	0.02
2	Canal Alamo	1	26.9	129.3	12.90	0.01
5	Canal Yucatán	3	26.7	123.2	13.10	0.01
6	Dren La Mesa	1	15.5	30.1	2.70	0.01
7	Río Nuevo	1	25.6	100.0	10.00	0.02
9	Dren Jalapa	3	20.6	63.6	9.47	0.02
11	Dren Nuevo León	1	25.6	132.7	16.60	0.02
15	Dren Carranza	2	21.0	49.3	5.50	0.04
21	Río Hardy	3	18.7	37.9	3.87	0.02
23	Canal Coahuila	3	21.1	51.2	5.67	0.04
25	Dren Welton	3	25.7	111.6	12.53	0.05
June 1986						
18	Río Hardy	4	24.0	66.2	12.20	0.09
19	Río Hardy	6	20.3	50.1	9.40	0.13
20	Río Hardy	5	22.8	63.2	11.90	0.10
22	Río Hardy	4	25.7	111.6	6.40	0.08
	Grand Mean $\bar{\bar{X}}$		63.9	20.3	6.98	0.05
C. fluminea		*n	(mm)			
February 1986						
1	Canal Campillo	3	30.56	1.40	0.20	0.16
2	Canal Alamo	2	35.28	2.97	0.48	0.06
3	Canal Galeana	3	25.92	1.34	0.30	0.04
1	Canal Independencia	2	33.40	2.98	0.75	0.06
6	Dren La Mesa	2	40.24	3.30	0.45	0.06
8	Canal Zaragoza	2	34.08	1.93	0.22	0.16
10	Canal Quintana Roo	3	23.72	1.15	0.28	0.07
13	Canal Cerro Prieto	2	32.28	2.71	0.54	0.08
14	Canal Sonora	3	26.12	1.14	0.20	0.11
16	Canal Caimán	2	29.72	1.48	0.21	0.15
23	Canal Coahuila	3	31.32	2.22	0.44	0.17
24	Canal Zacatecas	2	26.68	1.00	0.18	0.32
26	Río Colorado	2	31.52	2.62	0.62	0.02
27	Canal Km. 80	3	27.96	1.91	0.45	0.02
	Grand Mean $\bar{\bar{X}}$		30.63	2.01	0.38	0.11

*n Subsample of 25 organisms.

(Table 2). Data analysis performed at 0.05 confidence level by application of the Student's t-test revealed that there were no significant temporal differences among the fish caught in similar sites.

As indicated by the mercury levels in the organisms examined (Table 1), the Cerro Prieto geothermal field located within the rural area of Mexicali Valley is the major source of mercury pollution. However, clam samples collected far away from Cerro Prieto (Canal Coahuila and Canal Zacatecas) were

Table 2. Spatial variation of mercury concentrations (ug g^{-1} dry wt) in *T. mossambica* and *C. fluminea*. Means within same vertical column having same subscript are not significantly different $P > 0.05$.

Site	*T. mossambica* August, 1985	*T. mossambica* February, 1986	*T. mossambica* June, 1986	*C. fluminea* February, 1986
1				
2				0.16 C
3				0.16 B
4				0.04 AB
5	0.02 A	0.01 A		
6				
7				0.06 B
8				
9		0.02 AB		0.16 C
10				
11	0.03 AB			0.07 BC
12	0.14 C			
13				
14				0.08 BC
15	0.02 A	0.04 AB		0.10 BC
16				
17	0.07 B			0.15
18			0.09 A	
19			0.13 A	
20			0.10 A	
21	0.02 A	0.02 AB		
22			0.08 A	
23		0.04 AB		0.17 C
24	0.07 B			0.32 D
25		0.05 AB		
26				0.02 A
27				0.02 A

found to contain higher levels of mercury (0.17 - 0.32 ug/g) than samples collected within the geothermal field. These mercury anomalies reflected in these bivalves may yield information on the presence of shallow geothermal circulation patterns. According to Varekamp and Buseck (1983) geothermal surface features are accompanied by an mercury anomaly in soils. Also when geothermal fluids escape from a deep reservoir towards shallow levels, an mercury anomaly occurs in the overlying soils. The authors indicate that mapping of mercury soil anomalies can provide evidence regarding the presence and minimum extent of a geothermal system.

It is well established that, in many species of fishes mercury concentrations increase with increasing body weight (Koirtyohann et al. 1974), length (Friberg and Vostal 1972) or age (Bache et al. 1971). Linear regression expressions and correlation coefficients relating total mercury levels in muscle tissue to the weight and to the length of fish

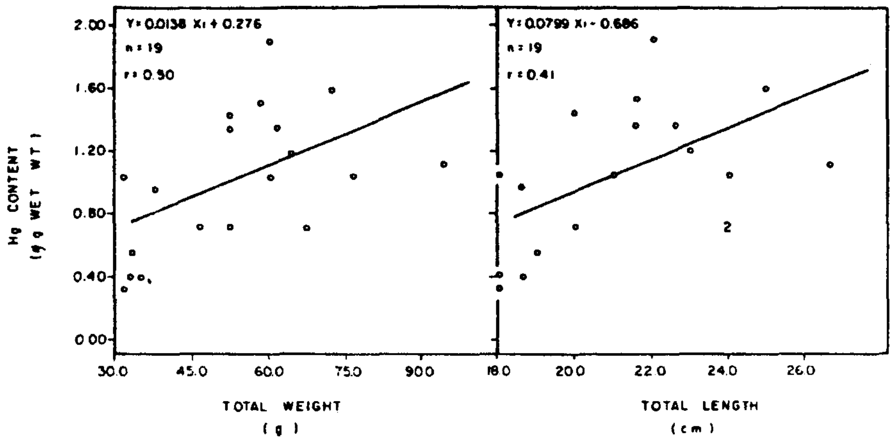

Figure 2. Relationship between body weight-total length of fish and total mercury content.

specimens were calculated to determine their relationship between these parameters. The correlation levels were low for both cases and only significant at the $P < 0.05$ level ($r= 0.50$) for the mercury content-wet weight relationship (Fig. 2). The low r values obtained may be attributed to the small sample and size range of the fish examined in this study. Another explication may be due to the bioavailability differences of mercury in the different sites of collection.

An important finding is that none of the fish and clam yielded mean mercury levels exceeding the widely accepted tolerance limit of 1.0 mg/kg (US Food and Drug Administration). Concentrations of mercury were particularly low and did not, in any case, approach a level which would give rise to public health concerns.

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