

Lead and Cadmium Concentrations in the Hair of Fishermen from the Subae River Basin, Brazil

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Previous studies have shown heavy pollution by lead and cadmium in the Subae River basin, State of Bahia, Brazil, caused by a lead smelter. Concentrations of these metals were determined in scalp hair of fishermen from three riverside towns and from a reference town. Increased levels for both metals were associated with increasing proximity to the smelter. Mean concentrations of lead and cadmium were higher among fishermen with straight hair than among those with curly hair. The effects of hair washing, hair type, and color and age on metal concentrations in fishermen's hair were studied.

INTRODUCTION

Since 1960 a primary lead smelter has been operating in the outskirts of Santo Amaro City, State of Bahia, Brazil (Fig. 1). Since its initiation it has been polluting the Subae River heavily. At least 2.5 tons of cadmium were dumped directly into the Subae River and another 1.5 tons released to the air. Total lead burden is difficult to estimate.

The environmental contamination was studied by Reis (1975) who showed that mean lead and cadmium concentrations in the Subae River water exceeded the World Health Organization (1977) tolerance limits by 16 and 8 times, respectively. Souza *et al.* (1978) found high concentrations of cadmium in local oysters, fish, crabs, and shrimps. Oysters (*Crassostrea rhizophorae*) are part of the usual diet of these populations and were particularly contaminated, mean concentration of cadmium averaging 120 ppm, ranging from 80 to 135 ppm, on dry weight basis. However, Carvalho (1978) did not find a significant association between the prevalence of proteinuria (sulfosalicylic acid method) and the ingestion of this local seafood by fishermen.

Despite the fact that no data on lead and cadmium in air were available, the aerial route should be an important source of human contamination by these metals. Emission of particulate metals to the atmosphere was uncontrolled because of the lack of adequate filters and very short chimneys (Carvalho, 1982).

We studied fishermen from the Subae River basin for absorption of lead and cadmium in relation to a reference population.

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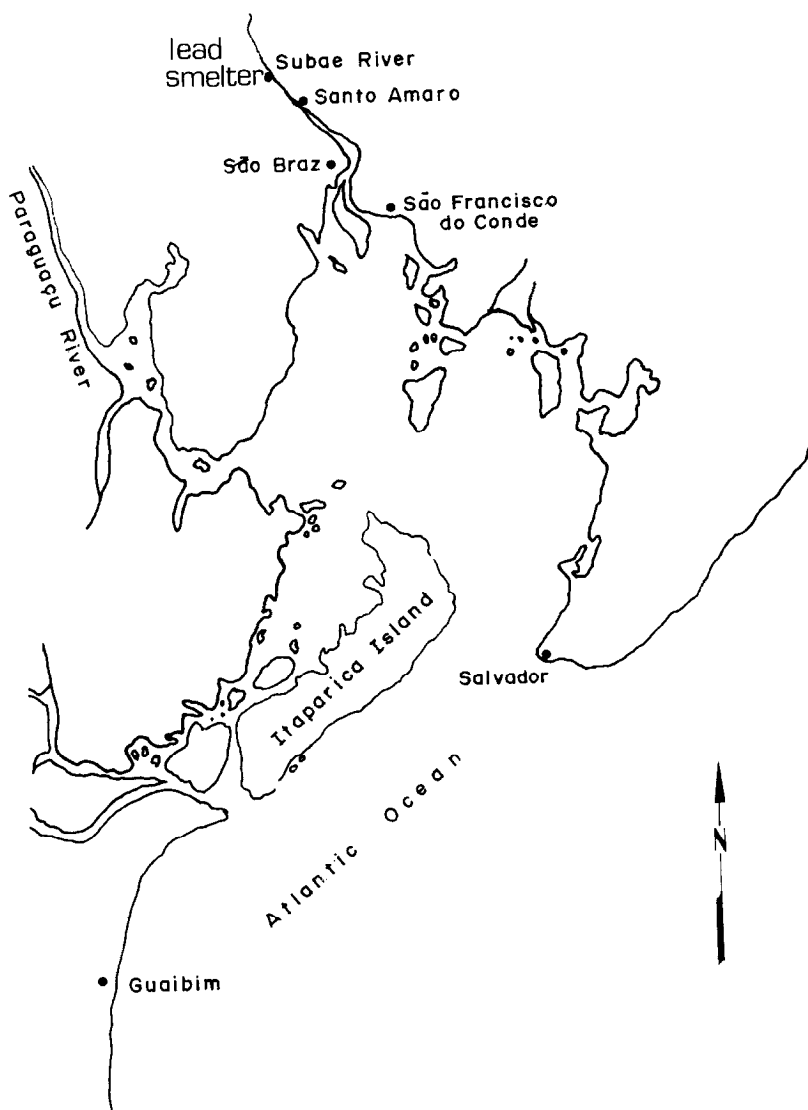


FIGURE 1.

MATERIALS AND METHODS

Simple random samples of 32, 35, and 52 fishermen were taken from riverside towns of Santo Amaro, Sao Braz, and Sao Francisco (sampling fractions: 0.55, 0.36, 0.23), respectively. Distances from the smelter were 3.5, 5.0, and 7.5 km, respectively. A reference population of 64 fishermen (sampling fraction: 0.77) was taken from Guaibim, a fishing village 84 km from the smelter. All 183 fishermen were males aged 18 to 77 years. Standards of living were very low for all four populations.

A hair sample was taken from each fisherman, hair strings being cut at the same distance from the scalp. Each sample was treated independently: about 1 g of hair was soaked for 1 hr in 50 ml of 10% neutral Extran with occasional stirring, then rinsed with deionized water and let to dry. The dried portion was transferred to a digestion pump, weighed with precision to 0.1 mg, and digested with 5 ml HNO₃ (concentrated) at 105°C for 8 hr. Readings were taken on an atomic absorption spectrophotometer Model 306, with graphite furnace HGA 2000, Perkin-Elmer (A Report, 1976).

Bartlett's test of homogeneity of variances (Kendall and Stuart, 1969) was applied to the data in Tables 1 and 2. Subsequent comparisons among town means were done by the Mann-Whitney test (Siegel, 1956). This same test was used to compare means, inside each town, for data on hair type, hair washing, and hair color.

Log PbH and log CdH represent, respectively, data on lead and cadmium concentrations in hair after logarithmic transformation, base 10.

RESULTS

Table 1 shows concentrations of lead in hair (PbH) and Table 2 of cadmium in hair (CdH) among fishermen from the four towns. \bar{X} represents the arithmetic mean; GM and SD_{GM}, the geometric mean and its respective standard deviation.

Each of the three populations from the Subae River area had higher PbH and CdH mean levels than those found in the reference population. Statistical significance levels for these comparisons were much higher for Santo Amaro ($P < 0.00005$), followed by those found in Sao Braz ($P < 0.0005$), and finally by those found in Sao Francisco ($P < 0.01$ for PbH and $P < 0.05$ for CdH).

Comparisons of PbH and CdH levels among fishermen from the three Subae River towns showed that those from Santo Amaro were more contaminated than those from Sao Braz ($P < 0.00005$ for each metal) and from Sao Francisco ($P < 0.00005$ for each metal). However, fishermen from Sao Braz had identical PbH and CdH means to those from Sao Francisco at the 5% significance level (not shown at Tables 1 and 2).

Table 3 shows that concentrations of lead and cadmium in hair were linearly related in fishermen from each town. Higher levels of association were observed in the polluted areas than in the reference area.

As can be seen in Table 4 fishermen with straight hair always presented higher

TABLE 1
CONCENTRATIONS OF LEAD IN SCALP HAIR (PbH, ppm) OF FISHERMEN FROM SUBAE RIVER TOWNS
AND FROM REFERENCE TOWN (GUAIBIM)

Town	N	\bar{X}	GM	SD _{GM}	Range	P
Santo Amaro	32	90.3	39.6	3.18	2-1168	<0.00005
Sao Braz	35	22.3	13.4	2.41	2-161	<0.0005
Sao Francisco	52	23.9	11.1	2.90	0-497	<0.01
Guaibim	64	13.3	6.9	3.20	0-87	—

TABLE 2
CONCENTRATIONS OF CADMIUM IN SCALP HAIR (CdH, ppm) OF FISHERMEN FROM SUBAE RIVER
TOWNS AND FROM REFERENCE TOWN (GUAIBIM)

Town	N	\bar{X}	GM	SD _{GM}	Range	P
Santo Amaro	32	1.72	1.01	2.70	0.18-9.89	<0.00005
Sao Braz	35	0.67	0.36	2.47	0.06-9.63	<0.0005
Sao Francisco	52	0.84	0.27	2.69	0.02-1.48	<0.05
Guaibim	64	0.97	0.15	4.18	0.01-4.20	—

PbH and CdH mean concentrations than those with curly hair. As related to PbH levels, these differences were statistically significant among fishermen from Santo Amaro ($P < 0.01$) and from Sao Francisco ($P < 0.05$). In relation to CdH levels, differences were statistically significant only among fishermen from Sao Francisco ($P < 0.01$).

In all towns, fishermen who used to wash their hair with soap had lower PbH and CdH mean concentrations than those who used only water (Table 5). However, not one of these differences reached the 5% significance level. Only one fisherman, from Sao Braz, declared he used to wash his hair with shampoo twice a week.

No marked differences in PbH and CdH mean levels were found ($P > 0.05$) in respect to hair color within each town (Table 6).

Linear regression equations were calculated for log PbH and log CdH in relation to age, for each town. No statistical associations were found at the 5% significance level.

DISCUSSION

Dosages of lead and cadmium in human hair have proved to be useful indexes of absorption following environmental exposure to these metals (Hammer *et al.*, 1971; Klevay, 1973; Chattopadhyay *et al.*, 1977; Kowal *et al.*, 1979). In this study, PbH and CdH concentrations showed that the absorption by the fishermen increased with increasing proximity to the smelter.

Carvalho *et al.* (1979) found that these same fishermen from Santo Amaro and

TABLE 3
LINEAR REGRESSION EQUATIONS FOR CONCENTRATIONS OF log PbH, ppm (Y) ON log CdH, AND ppm (X) OF FISHERMEN FROM SUBAE RIVER TOWNS AND FROM REFERENCE TOWN (GUAIBIM)

Town	N	Equation	r^a	P^b
Santo Amaro	32	$Y = 1.595 + 0.502.X$	0.43	≤ 0.007
Sao Braz	35	$Y = 1.290 + 0.362.X$	0.37	≤ 0.01
Sao Francisco	52	$Y = 1.425 + 0.607.X$	0.52	≤ 0.00004
Guaibim	64	$Y = 0.912 + 0.098.X$	0.12	≤ 0.17

^a r = correlation coefficient.

^b P = significance of the slope.

TABLE 4
CONCENTRATIONS OF LEAD AND CADMIUM IN SCALP HAIR OF FISHERMEN FROM SUBAE RIVER TOWNS
AND FROM REFERENCE TOWN (GUAIBIM) BY HAIR TYPE

Town	Hair type	N	PbH			CdH		
			GM	SD _{GM}	P	GM	SD _{GM}	P
Santo Amaro	Straight	11	86.4	3.09	<0.01	1.17	2.53	>0.05
	Curly	16	25.4	2.93		0.90	2.97	
Sao Braz	Straight	4	19.0	6.10	>0.05	0.56	1.97	>0.05
	Curly	29	12.7	2.12		0.33	2.54	
Sao Francisco	Straight	5	44.7	4.64	<0.05	0.66	1.54	<0.01
	Curly	47	9.8	2.48		0.22	2.43	
Guaibim	Straight	5	6.7	4.02	>0.05	0.21	2.60	>0.05
	Curly	58	6.6	3.08		0.15	4.38	

from Sao Braz had higher levels of δ -aminolevulinic acid in urine than the reference group from Guaibim town ($P < 0.05$). This further evidence indicates that, beyond being absorbed, environmental lead is impairing heme biosynthetic pathways of these fishermen. Recently, Carvalho (1982) carried out a survey among 642 children 1- to 9-years-old living at less than 900 m from the Santo Amaro smelter. Geometric mean of zinc protoporphyrin concentrations was 1.29 ± 2.26 $\mu\text{mol/liter}$ and the arithmetic mean of blood lead levels was 2.84 ± 1.20 $\mu\text{mol/liter}$. Carvalho (1978) determined prevalence rates of proteinuria by the sulfosalicylic acid method among fishermen from these four towns. Rates were higher, in Santo Amaro (7.0%), Sao Braz (7.2%), and Sao Francisco (5.6%) than in Guaibim (4.8%). However, these differences were not statistically significant at the 5% level.

Both contaminated and reference populations presented here had CdH mean levels somewhat lower than those recorded in other studies, carried out among non-occupationally exposed adult males (Petering *et al.*, 1973; Oleru, 1975; Gross *et al.*, 1976; Kowal *et al.*, 1979).

TABLE 5
CONCENTRATIONS OF LEAD AND CADMIUM IN SCALP HAIR OF FISHERMEN FROM SUBAE RIVER TOWNS
AND FROM REFERENCE TOWN (GUAIBIM) BY HAIR WASHING

Town	Hair wash	N	PbH		CdH	
			GM	SD _{GM}	GM	SD _{GM}
Santo Amaro	Water	7	53.3	1.86	1.09	2.16
	Soap	23	36.4	3.74	1.03	2.93
Sao Braz	Water	5	19.5	6.02	0.52	2.41
	Soap	27	12.8	2.00	0.34	2.51
Sao Francisco	Water	7	16.0	2.39	0.27	2.06
	Soap	43	10.9	3.04	0.24	2.63
Guaibim	Water	6	9.7	4.04	0.28	4.18
	Soap	58	6.6	3.15	0.14	4.18

TABLE 6
CONCENTRATIONS OF LEAD AND CADMIUM IN SCALP HAIR OF FISHERMEN FROM SUBAE RIVER TOWNS
AND FROM REFERENCE TOWN (GUAIBIM) BY HAIR COLOR

Town	Hair color	N	PbH		CdH	
			GM	SD _{GM}	GM	SD _{GM}
Santo Amaro	White/Grey	14	36.5	2.41	1.04	2.96
	Brown	8	43.4	4.44	0.96	3.33
	Black	6	51.3	5.25	1.02	1.70
Sao Braz	White/Grey	3	26.2	5.08	0.58	3.19
	Brown	16	13.9	1.98	0.37	2.88
	Black	16	11.4	2.48	0.31	2.02
Sao Francisco	White/Grey	13	10.9	2.81	0.26	2.26
	Brown	20	10.8	3.57	0.21	2.69
	Black	19	12.2	2.43	0.27	2.50
Guaibim	White/Grey	12	6.7	3.07	0.27	2.88
	Brown	6	4.4	4.31	0.14	2.28
	Black	46	7.3	3.16	0.13	4.74

Petering *et al.* (1973) studied a non-occupationally exposed population with similar age and sex composition. PbH mean level was 44.4 ppm which is still higher than values observed in the present study. PbH mean values for non-occupationally exposed groups vary widely due to differences in biological characteristics among study populations (Schroeder and Nason, 1969; Hammer *et al.*, 1971; Klevay, 1973; Chattopadhyay *et al.*, 1977). Comparisons of PbH and CdH levels among various studies can lead to fallacious conclusions due to different analytical methods (Friberg *et al.*, 1974; Kopito and Shwachman, 1974).

For males aged 2 to 88 years, Petering *et al.* (1973) found that log PbH and log CdH were highly associated ($r = 0.40$; $P < 0.001$). Similarly high levels of association were observed between these two variables among fishermen from the Subae River area.

Fishermen with straight hair presented higher PbH and CdH concentrations than those with curly hair. These variations seem to depend more on biological factors than on exposure level. The effect of different racial groups on these results was not assessed because the high racial admixture prevailing in this population makes this task particularly difficult.

Constantly lower PbH and CdH levels were observed among fishermen who used to wash their hair with soap, instead of only water. It is a well-known fact that nonionic detergents and organic solvents are effective in removing heavy metals from hair surface (Friberg *et al.*, 1974; Grandjean, 1978). Therefore, a possible explanation for the figures observed in Table 5 is that the poor-quality, alkaline soap commonly used by these fishermen would attack the hair surface. In this way, certain amounts of endogenous lead and cadmium could be removed.

No significant differences at the 5% level were found in PbH and CdH means in relation to hair color. Schroeder and Nason (1969) found that, among males, brown hairs accumulated more lead and cadmium than black ones. As in our study, they also found that white and grey hairs did not have higher lead and cadmium concentrations than natural colored hairs at the 5% significance level.

As in the present study, Petering *et al.* (1973) did not find statistical association ($P > 0.05$) between log PbH and log CdH and age, using linear regression.

Summarizing, variations observed among the biological parameters cited above were very useful to explain some differences in PbH and CdH indexes among the four fishermen populations. However, the main point which emerged from this study was the human contamination by lead and cadmium caused by gross environmental pollution produced by the industry.

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