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Use of Hair as an Indicator of Environmental Lead Pollution in Women of Child-bearing Age in Karachi, Pakistan and Bangladesh

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The continued use of leaded gasoline and lead-based paints in the Indian sub-continent has resulted in widespread exposures to lead (Sinclair et al., 1973; Aggarwal et al., 1979; Khandekar et al., 1984). While blood lead (Pb) is used clinically to determine the severity of Pb poisoning, blood Pb levels are most useful if sampled within 4 weeks of exposure (Laker, 1982). It has been reported that blood Pb levels peak within 4-5 hours following inhalation of airborne Pb and after about 24 hours following ingestion of Pb. Thus, intermittent or cumulative exposures to Pb, as might occur following chronic exposures may be more accurately assessed by measuring hair Pb levels with the proviso that external contamination can be ruled out (Laker, 1982). In general, for certain metals, hair is less prone to short-term fluctuations and since hair analysis is non-invasive, it lends itself to repeated samplings over time. Hair analysis has also been used successfully to document nutritional deficiencies of essential trace elements like zinc and selenium (Chen et al. 1980) and environmental exposures to potentially toxic metals like mercury, Pb, iron and arsenic (Wibowo et al., 1986; Limic and Valkovic, 1986; Jamall and Jaffer, 1987; Chatt and Katz, 1988).

The present study was prompted by an observation made during a visit to Karachi in 1986 when three blood samples from two women and a man, all between 30-35 years yielded blood Pb levels of 31.4, 21.9 and 41.7 ug Pb/dl blood (unpublished observations). Karachi is a highly industrialized urban center (pop. 5.1 million) with very large numbers of motor vehicles, all of which use leaded gasoline. Lead-based paint is also extensively used in the city. The present study was conducted to determine if hair metal analyses could be

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used to determine elevated exposures to lead in women of child-bearing age living in Karachi (Pakistan). Rural Bangladeshi women living in areas with little or no vehicular traffic and no factories in the vicinity were used as controls.

MATERIALS AND METHODS

Hair samples were collected at random from 41 women (mean age 33 years, range 18-55 years) residing in the city of Karachi, Pakistan, during December 1986-January 1987. Samples of approximately one inch in length were taken from the nape of the neck because of cosmetic considerations and because "new growth" hair was needed since this would more closely reflect body burden. All participants were questioned about the use of hair dyes, those that had used any dye were excluded from the study. Hair samples were also collected from 42 age-matched women (mean age 30 years, range 16-51 years) from a rural area in Southeastern Bangladesh with no factories sited within 50 miles of the villages and with little or no vehicular traffic. Informed consent was obtained from each subject at the time of sampling. Each hair sample was placed in an envelope with the name, age and occupation the individual.

All hair samples were washed in 8% (w/v) sodium lauryl sulfate, acetone and deionized water according to the method of Petering et al. (1971) modified as described (Jamall and Jaffer, 1987). This wash procedure minimizes contamination from externally-adsorbed metals as previously reported (Jamall and Jaffer, 1987). Pb, zinc (Zn) and copper (Cu) levels in each sample were determined by atomic absorption spectrometry using a Perkin-Elmer 2380 AAS following wet acid digestion using trace metal grade ultrapure concentrated nitric acid. Statistical significance was assessed using the Cochran and Cox option of the PROC TTest of the SAS (SAS Institute, 1987). p levels of 0.05 or less were considered to be significant.

RESULTS AND DISCUSSION

Our data indicate that asymptomatic women living in the city of Karachi have approximately 600% higher Pb levels in their hair than their age-matched counterparts living in a rural environment in Bangladesh (Table 1). The extent of the environmental Pb exposure in Karachi versus Bangladesh is illustrated in Table 2 which gives the cumulative distribution of hair Pb in the two population samples. Approximately

Table 1. Lead, zinc and copper levels in scalp hair from women living in Karachi, Pakistan and Bangladesh

Location	N	Hair Metal Levels (ug metal/g hair) Pb	Zn	Cu
Karachi	41			
Arith. X ± S.D.		31.7 ± 24.9*	199.5 ± 65.2*	14.9 ± 4.6*
(Min-Max)		(7.4 - 144.0)	(54.5 - 417.0)	(7.4 - 32.6)
Geom. X ± S.D.		26.4 ± 1.8	188.6 ± 1.4	14.3 ± 1.3
Bangladesh	42			
Arith. X ± S.D.		5.0 ± 5.3	120.1 ± 43.3	30.7 ± 27.0
(Min-Max)		(0.2 - 20.2)	(53.8 - 302.6)	(9.7 - 175.6)
Geom. X ± S.D.		2.6 ± 3.6	113.9 ± 1.4	25.3 ± 1.8

The Cochran and Cox option of PROC TTEST of SAS results in statistical significance (* = $p < 0.001$) for all of the mean hair metal levels (Pb, Zn and Cu) for Karachi versus Bangladesh (SAS Institute Inc., 1987).

Table 2. The cumulative distribution of lead in hair from women in Karachi and Bangladesh

Cell	ug Pb/g hair	Frequency	Percent	Cumulative frequency	Cumulative percent
Karachi					
1	0 - 5.0	0	0	0	0
2	5.1-10.0	2	4.9	2	4.9
3	10.1-15.0	2	4.9	4	9.8
4	15.1-20.0	8	19.5	12	29.3
5	20.1-25.0	8	19.5	20	48.8
6	25.1-30.0	7	17.1	27	65.9
7	30.1-35.0	6	14.6	33	80.5
8	35.1-40.0	0	0	33	80.5
9	40.1-45.0	3	7.3	36	87.8
10	45.1-	5	12.2	41	100.0
Bangladesh					
1	0 - 5.0	27	64.3	27	64.3
2	5.1-10.0	8	19.0	35	83.3
3	10.1-15.0	5	11.9	40	95.2
4	15.1-20.0	1	2.4	41	97.6
5	20.1-25.0	1	2.4	42	100.0

50% of the Karachi women had hair levels above 25 ug Pb/g whereas none of the women in rural Bangladesh had levels above 25 ug Pb/g hair (Table 2). These elevated hair Pb levels confirm our findings of high blood Pb levels in two women in Karachi (31.4 and 21.9 ug Pb/dl blood; hair Pb levels 42.6 and 33.4 ug Pb/g hair, respectively). These blood Pb levels are much higher than those reported in mothers (mean 9.2 $\pm$ 2.7 ug Pb/dl blood) living in Sao Paulo, a large city in Brazil where leaded gasoline is still used and which is reported to have a high degree of environmental pollution (Troster and Schvartsman, 1988). It should be noted that blood Pb levels in adults (n=77) living in Bombay, India, a highly industrialized urban center ranged from 2.9-41.2 ug Pb/dl blood (Khandekar et al. 1987). High hair Pb levels (mean 90.3, geom. mean 39.6, range 2-1168, n=32) have been reported in male fishermen living near a Pb smelter in Santo Amaro, Brazil (Carvalho et al., 1984).

Only a few published reports are available on Pb levels in the hair of women of childbearing age. One such study (Huel et al., 1984) of 104 mother-newborn pairs reported a mean maternal hair Pb level of 8.4 ug Pb/g hair, not disimilar from our findings for rural Bangladeshi women. Another study (Rockway et al., 1984) reported a hair value of 2.0 $\pm$ 1.8 ug Pb/g hair in 39 lactating women in Arizona. These women had mean blood Pb levels of 11.9 ug Pb/dl blood.

The Pb levels reported in our sample of rural Bangladeshi women compare favorably with those from areas with little use of leaded gasoline. For instance, a study of 261 women aged 16-49 years in the United Kingdom with a mean hair Pb of 5.6 ppm and a range of 0-12 ppm Pb (Barlow et al., 1985). Another study of women (n=45) aged 21-50 years in Christchurch, New Zealand reported mean hair Pb levels of 9.6 ppm, geometric mean of 8.5 and a range of 3.0-21.2 ppm Pb. In this same report, women (n=20) with potential Pb exposure through outdoor jobs had a mean hair Pb of 30.4, range 3.2-110.9 ug Pb/g hair (Fergusson et al., 1981).

While, the published data on hair Pb does not as yet justify its use in determining the severity of Pb toxicity, hair Pb levels have been used as a monitoring tool for elevated environmental exposures to this metal (Carvalho et al., 1984; Wibowo et al., 1986). Blood levels peak 4-5 hours after inhalation of airborne Pb and approximately 24 hours after ingested Pb (Laker, 1982). Thus, appropriately used, and once the data are more extensively documented, hair Pb levels might be a useful means of monitoring environmental Pb exposure.

The data in Table 1 indicate that women in Karachi have approximately 66% higher hair Zn levels compared to their Bangladeshi counterparts. A simple explanation for this difference might be differences in dietary Zn intake in the two population samples, possibly influenced by dietary differences. Hair values in a sample of 261 British women were reported to be 183.2 ug Zn/g hair (Barlow et al., 1985). Greger et al. (1978) reported a mean value for hair of 192$\pm$32 ug Zn/g hair for menstruating females. While Eads and Lambdin (1973) reported a mean hair level in women in Port Arthur, Texas and Hanover, New Hampshire of 172 ug Zn/g hair.

Hair Zn levels have been used to detect nutritional deficiencies of this essential trace element (Hambidge et al., 1976). In children, it has been suggested that hair Zn levels <70 ug Zn/g hair are indicative of a severe Zn deficiency (Committee on Nutrition, 1978). Hair Zn levels lower than this vale have been reported in patients with Acrodermatitis enteropathica, the gentic Zn deficiency condition (Amador et al., 1975). Of the Bangladeshi women sampled 26% had hair levels below 90 ug Zn/g hair whereas only 2% of the women from Karachi had hair Zn levels in this range (data not shown).

Hair Cu levels in Bangladeshi women were significantly higher than those in women from Karachi (25.3 versus 14.3 ug Cu/g hair). The significance of this difference in hair Cu is unclear. Normal adults in the U.S. have been reported to have mean (geometric) hair Cu values of 16.3 (Paschal et al., 1989), not dissimilar from the Karachi women in this study and in agreement with pooled world-wide values of 17.3 $\pm$ 6.6 with a range of 6.8 to 39 ppm Cu (Iyengar and Wottiez, 1988). However, Barlow et al. (1985) reported a mean of 38.5 ppm Cu in scalp hair from a sample of 261 British women aged 16-49 years. Data from our laboratory indicate that caucasian American women of child-bearing age (n=13) have mean hair Cu levels of 33.4 $\pm$ 8.4 ppm Cu (unpublished observations).

Our observations document elevated Pb exposures in women of child-bearing age in Karachi and suggest that Pb exposures in this city may be greater than those reported from large urban areas in India (Sinclair et al., 1973; Aggarwal et al., 1979; Khandekar et al., 1984). Given the high degree of susceptibility of infants and children to serious, irreversible brain damage and learning deficits from chronic environmental Pb exposures, it is imperative that further characterization of the magnitude of this problem be conducted among residents of Karachi and other large urban centers in Pakistan in order to mitigate the toxic effects of Pb.

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