Bull. Environ. Contam. Toxicol. (1987) 39:608–614

Bulletin of Environmental Contamination and Toxicology

Elevated Iron Levels in Hair from Steel Mill Workers in Karachi, Pakistan

I. Siraj Jamall[1] and R. A. Jaffer[2]

[1]Toxicology Program, St. John's University, Jamaica, New York 11439 and
[2]Staff Health Clinic, Pipri Steel Mills, Karachi, Pakistan

Over the last two decades, much interest has been focused on the use of trace metals in human hair to diagnose nutritional deficiencies of these metals or toxicities of metals such as lead or organic mercury (Kopito et al., 1967;Hammer et al., 1971; Eads and Lambdin, 1973; Corridan, 1974; Wibowo et al., 1986; Gonzalez et al., 1986). Although, the diagnostic value of zinc (Zn), copper (Cu), lead and mercury levels in human hair have been well established, little information is available on the significance of iron (Fe) levels in hair to diagnose nutritional deficiency or toxicity of this metal. The present study was conducted to determine if occupational exposure in the steel industry resulted in alterations in the levels of Fe, Zn, and Cu in hair and could thus serve as a simple tool for monitoring exposure to potentially hazardous levels of these metals.

MATERIALS AND METHODS

Hair samples were collected at random during the winter of 1983 from apparently healthy workers accompanying their wives to the obstetric/gynecology clinic at a steel mill in Karachi, Pakistan. Samples were taken from the nape of the neck of 26 workers. Samples were also collected from 28 age- and sex-matched control Pakistani men in the city of Karachi, primarily students, to enable a comparison of hair metal profiles between two nutritionally similar groups differing only in their occupation. 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 of the individual.

All hair samples were washed according to the method of

Send reprint requests to I. Siraj Jamall at the above address.

Petering et al. (1971) modified as follows: Approximately 200 mg samples of hair were placed in acid-washed (metal free) 50 ml Pyrex beakers. Each sample was first immersed in 20 ml acetone for 10 minutes with occasional stirring. The acetone was decanted and the samples immersed in a 8% (w/v) solution of sodium lauryl sulfate for 10 minutes, again with occasional stirring. The hair samples were then poured onto a 5 cm filter connected to a Buchner funnel and washed three times with deionized water, under suction. A final rinse with acetone ensured removal of all detergent. The samples were next rinsed with deionized water three times, covered with another piece of filter paper and allowed to air dry for 30 minutes. Samples were then weighed and placed in metal-free 50 ml Pyrex beakers, covered with a watch glass and wet-ashed in 25 ml conc. HNO_3 for 24 hours on a hot plate in a hood to avoid contamination. Ashed samples were redissolved in 10% HNO_3 and read for Fe, Zn and Cu levels were determined by atomic absorption spectrometry using a Perkin-Elmer 2380 AAS as described (Jamall and Sprowls, 1987).

In order to ascertain whether the high Fe levels in hair represented external contamination of hair or reflected elevated body stores of Fe, known weights of unwashed hair samples from five steel workers and 5 controls were immersed in 10 ml of a 10 mM EDTA (pH7.0) solution in metal-free Pyrex beakers and covered with parafilm. Blanks consisted of 10 ml of the EDTA solution in beakers containing no hair. After 150 minutes at room temperature, a 5.0 ml aliquot of the EDTA from each beaker was taken and analyzed without further treatment for Fe by atomic absorption spectroscopy. The Fe levels leached out into the EDTA are reported as a percentage of the dry weight of each hair sample taken.

RESULTS AND DISCUSSION

The results indicate that steel workers had 4-fold higher mean Fe levels in their hair as compared to age-matched controls (Table 1). Since Fe is also a nutritionally essential metal, the increased Fe levels in hair of steel workers could be due to differences in diet between workers and the controls chosen. That this difference in Fe is not due simply to nutritional differences between the steel workers and control groups is borne out by the fact that the two other essential metals assessed, Zn and Cu, were not significantly different between the two groups examined (Table 1).

In order to ascertain the source of the high Fe levels in the hair of the steel workers, an experiment was

done in vitro to determine if the Fe was adsorbed on the hair from the work environment or reflected body burden of this metal. Although different amounts of Fe were leached out into the EDTA solution from each control and worker hair sample (Table 2), there was no difference in the Fe leached out by the EDTA wash when expressed as a percentage of metal in hair, ug Fe/g hair. These data suggest that the high Fe levels in the hair of the steel mill workers may be a reflection of increased body burden of this metal. Although all of the workers sampled were asymptomatic at the time of sampling, high Fe levels have been implicated in peroxdative injury (Slivka et al., 1986) and constitute a risk of developing hemosiderosis and hepatotoxicity (Gordeuk et al., 1986). Measurements of plasma Fe, serum transferrin and total iron binding capacity (TIBC) would help confirm our observations. However, our results do indicate that these workers are in fact exposed to high levels of Fe in their work environment and that long-term health effects due to the high Fe exposure cannot be ruled out.

A thorough search of the literature revealed a paucity of information on Fe levels in hair and its biological significance. A study of metal levels in hair from students and non-students in Oxford (Reilly and Harrison, 1979) found that male students at Oxford had a mean Fe level of 11.2 $\pm$ 0.5 ppm (n=42). Non-student males had Fe levels of 13.0 $\pm$ 0.8 ppm (n= 80). Other authors cite similar Fe levels viz., Harrison et al. (1969) reported a mean Fe level in hair of 15.3 ppm in samples taken from 18 adult American males. Creason et al. (1975) reported levels of 22.3 ppm Fe (geometric mean) in hair samples from 202 adults (not identified by sex) in New York City. In another study (Briggs et al., 1972) on adult males in Lusaka, Zambia, Fe levels in hair were reported to be 31 $\pm$ 2.0 ppm (n=74), somewhat higher than our control values but still considerably lower than those found in the steel workers in this study. These values are at least 50% lower than Fe levels in hair from the control Pakistani men in the present study (Table 1).

As indicated in Table 1, mean Zn levels in hair samples from steel workers and control Pakistani men were not significantly different. These values are consistent with Zn levels in hair from males reported in several different studies from different parts of the world (Reilly and Harrison, 1979; Briggs et al., 1972; Chittleborough, 1980). Zinc Values reported by Creason et al. (1975) for adults in New York City (108.54 ppm Zn geometric mean, n= 167) were somewhat lower than those in our sample of Pakistani men and below values for other Caucasian males cited above (Reilly and Harrison, 1979).

Table 1. Iron, zinc and copper in human hair (ug/g) of steel workers and control males in Karachi, Pakistan

		ug metal/g hair		
Sample	Age	Iron	Zinc	Copper
1	24	53.3	211	11.4
2	24	132	175	10.6
3	24	47.7	179	10.5
4	22	46.9	225	11.9
5	23	86.2	216	13.3
6	33	106	235	16.0
7	30	106	212	9.77
8	21	69.5	220	6.13
9	22	90.1	194	9.24
10	34	50.4	231	13.4
11	32	51.6	181	5.47
12	32	51.6	199	12.1
13	23	98.6	101	9.71
14	21	80.5	179	9.72
15	28	178	185	11.4
16	27	168	114	25.8
17	21	141	131	9.95
18	34	158	149	10.9
19	30	103	124	11.2
20	26	113	184	10.1
21	22	67.6	197	10.0
22	25	69.4	221	11.9
23	22	84.0	201	11.4
24	22	43.8	144	9.37
25	26	82.0	192	10.8
26	20	93.0	244	11.9
Workers				
Arithmetic Mean		91.2*	186ns	11.3ns
S.D.		38.6	38.6	3.61
Controls (N=28)				
Arithmetic Mean		23.6	184	11.8
S.D.		8.28	40.3	2.85

*Significantly different from Controls by $P < 0.01$ One Way ANOVA; ns = Not significantly different from controls

Table 2. Percentage of EDTA-chelatable iron leached from control and steel worker hair samples[1]

Sample No.	Hair Wt. (g)	Fe in EDTA wash (ppm)	Total Fe in wash (ug)	Total Fe leached out of hair (ug/g)	Hair Fe (ppm)	Percentage Fe leached out of hair
Controls						
1	0.1052	0.034	0.169	1.61	31.6	5.11
2	0.1200	0.016	0.080	0.667	17.4	3.83
3	0.1011	0.011	0.055	0.544	18.8	2.89
4	0.1000	0.006	0.030	0.300	15.4	1.95
5	0.1037	0.019	0.095	0.916	28.0	3.27
					Mean	3.41
					± SD	1.17
Workers						
1	0.0886	0.055	0.275	3.10	98.8	3.14
2	0.1204	0.041	0.205	1.70	80.6	2.11
3	0.0577	0.037	0.185	3.21	178	1.80
4	0.0832	0.032	0.160	2.81	68.4	4.11
5	0.1091	0.165	0.825	7.56	141	5.36
					Mean	3.30
					± SD	1.47

[1]Hair samples were immersed in a 10 mM EDTA solution (pH 7.0) for 150 minutes. Fe levels were measured in a 5 ml aliquot of the EDTA solution. Hair samples were washed repeatedly and processed for hair Fe determination. Total Fe leached into the EDTA was then normalized for weight of hair sample taken and expressed as a percentage of total Fe in that hair sample.

Levels of Cu in hair in the steel workers did not differ significantly from controls (Table 1). However, these values are about 50% lower than those reported in males in the Oxford study (Reilly et al.,1979; Harrison et al., 1969). Creason et al.(1975) reported a geometric mean Cu level of 18.25 (n=204) in hair taken from adults in New York City. These values for Cu levels in human hair are not significantly different from the levels in our study.

Our observation of elevated Fe levels in human hair provides a simple means of monitoring workers for exposure to potentially toxic levels of this metal. The use of EDTA to assess chelatable Fe *in vitro* may serve as a means of distinguishing between Fe adsorbed onto hair and that reflecting increased body burden in the absence of blood chemistry.

REFERENCES

Briggs MH, Briggs M, Wakatama A (1972) Trace elements in human hair. Experientia 28: 406

Chittleborough G (1980) A chemist's view of the analysis of human hair for trace elements. Sci Total Environ 14: 53-75

Corridan JP (1974) Head hair samples as indicators of environmental pollution. Environ Res 8: 12-16

Creason JP, Hinners TA, Bumgarner JE, Pinkerton C (1975) Trace Elements in hair as related to exposure in metropolitan New York. Clin Chem 21: 603-612

Eads EA, Lambdin CE (1973) A survey of trace metals in human hair. Environ Res 6: 247-252

Gonzalez MJ, Rico MC, Hernandez LM, Baluja C (1986) Mercury in human hair. Arch Environ Health 40:225-228

Gordeuk V, Boyd RD, Brittenham GM (1986) Dietary iron overload persists in rural Sub-Saharan Africa. Lancet, June 7: 1310-1313

Hammer DI, Finklea JF, Hendricks RH, Shy CM, Horton RJM (1971) Hair trace metal levels and environmental exposure. Am J Epidemiol 93: 84-92

Harrison WW, Yurachek JP, Benson CA (1969) The determination of trace elements in human hair by atomic absorption spectroscopy. Clin Chim Acta 23: 83-916

Jamall IS, Sprowls JJ (1987) Effects of cadmium and dietary selenium on cytoplasmic and mitochondrial antioxidant defense systems in the heart of rats fed high dietary copper. Tox Appl Pharmacol 87:102-110

Kopito L, Byers RK, Schwachman H (1967) Lead in hair of children with chronic lead poisoning. N Engl J Med, 276: 949-953

Petering HG, Yeager DW, Witherup SO (1971) Trace metal content of hair. I. Zinc and copper content of human hair in relation to age and sex. Arch Environ Health 23:202-207
Reilly C, Harrison F (1979) Zinc, copper, iron and lead in scalp hair of students and non-student adults in Oxford. J Human Nutr 33: 248-252
Slivka A, Kang J, Cohen G (1986) Hydroxy radicals and the toxicity of oral iron. Biochem Pharmacol 35:553-556
Wibowo AAE, Herber RFM, Das HA, Roeleveld N, Zielhuis Z (1986) Levels of metals in hair of young children as an indicator of environmental pollution. Environ Res 40:346-356
Received March 23, 1987; accepted June 28, 1987.