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Trace Metal Contamination Study on Scalp Hair of Occupationally Exposed Workers

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Scalp hair is a metabolic end product that incorporates metals into its structure during the growth process. The levels of trace elements in the hair are considered to be influenced in particular by food, air and occupational exposure, and in general by race, age, sex (Takeuchi 1982;Costa 1989.), metabolism, hygienic condition (Krishna 1987) and geographical location of individuals (Sarmani 1987; Ward 1987;Ahmed 1990; Eltyb 1990). Recently, trace metal content of human hair has been explored as a tool for monitoring the impact of environmental pollution on the inhabitants of a community (Limic 1986;Lal 1987;Takeuchi 1987;Stewart 1989;Lyubchenko 1989; Jamal 1990). In this respect, the endogenous and exogenous contents of metals in hair are understood to play important role towards exposure assessment.

The exogenous metal content of hair reflects exposure to the occupational, domestic and recreational environments, provided the donor is not suffering from heavy metal poisoning and depressed endogenous levels arising from dietary deficiencies (Chatt and Katz 1988). Keeping this in view, the exogenous and endogenous metal contents of scalp hair of occupationally exposed workers from various workshops were determined in the present study,both in unwashed and washed hair samples to assess the extent of metal contamination. All donors, within the age group of 6-45 years, were full-time workers of various autoworkshops situated in the densely populated and industrialized city of Lahore. ICP atomic emission and atomic absorption spectrophotometric methods were used for determining the levels of five non-essential and three essential elements in the scalp hair.

MATERIALS AND METHODS

Workers from mechanical workshops, automobile service

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centers and public transport maintenance cells were selected for sampling. All hair samples, weighing about 1.5g each and comprising of 1-5 cm long strands, were collected in new strong polythene bags.Each sample was divided into two parts; one of these was washed with distilled water to remove dust, defatted with acetone and washed again with deionized water (Ryabukhin 1977). The washed and unwashed samples were oven-dried at $60 \pm 2^{\circ}C$ for 12 hours. An accurately weighed 0.500 g of each sample was taken separately into a previously acid washed and dried Erlenmayer flask and treated with 5.0 mL of concentrated nitric acid (suprapure,69%). The acid was allowed to react at room temperature to prevent foaming. The content of each flask was then heated and treated with 1.0 mL of perchloric acid (70%). The digestion was continued till dense white fumes were evolved, marking the completion of the process (Chatt and Katz 1988). The content of the flasks were transferred to a 50.0 mL volumetric flask and the volume was made upto the mark with 2% nitric acid. Inductively Coupled Plasma Atomic Emission Spectrometer (JY-48 Spectroanalyser) was used for the analysis of Co, Na, K, Ni, Pb and Zn in the digested samples, while a Shimadzu Atomic Absorption Spectrophotometer (AA-670), interfaced with a hydride generator and a mercury analyser, was used for the analysis of As and Hg. Three subsamples of each hair sample, digested separately, were run simultaneously.Results of triplicate measurements, which agreed within $\pm 1.5\%$, were averaged on dry weight basis. To study the correlation between endogenous and exogenous metal contents, comparison between the respective averages was conducted using MSTAT programme on a Dell 386 DX Computer(Freed 1990). Parallel metal estimations were made on IAEA reference material, HH-1 to validate the estimated metal concentrations in hair.

RESULTS AND DISCUSSION

The concentrations of various metals in washed scalp hair of donors, within the age group of 6-45 years, are reported in Table 1.The data showed a distinct dispersion in the concentration of almost each metal, not apparently related to age. Within the restricted frequency of sampling ($1 < n < 3$) the concentration values were found to diverge for the same frequency of a given age group.It thus turned out that age was not a critical variable correlated with concentration of various metals in hair, at least through endogenous route.

Of all the metals investigated Na and Zn showed the highest concentration levels, followed by K(Table 2). Lead showed substantially high levels, followed by Ni, an industrially important metal.As and Co were the next trace elements with a minimum concentration approaching about 1.0μg/g. Since a distinct age dependence of metal concentrations was not apparent on the basis of present study, the data were examined as a means of differentiation between the endogenous and exogenous contributions.

Table 2 summarizes this comparative situation in terms of metal concentrations in unwashed and washed hair. The unwashed to washed hair metal concentration ratio was found to be 1.70 for Pb, and a relatively lower ratio, 1.22 for Hg, and 1.15 and 1.17 for Ni and As. These values, therefore, evidenced a positive exogenous contribution of industrial metals Pb, Hg, As and Ni,in the hair of occupational workers. The finding was duly supported by the metal-to-metal correlation coefficient study (Table 3) conducted for washed hair samples.

Table 1.Levels of selected metals(ug/g;dry weight) in washed scalp hair of workers from Lahore

S.No.	Age	As	Co	Hg	K	Na	Ni	Pb	Zn
1	6	N.D.	0.2	0.91	104.8	457.1	N.D.	9.9	37.4
2	7	0.77	1.0	1.80	173.0	534.4	5.8	15.0	201.2
3	17	0.50	1.2	1.40	160.6	287.8	4.7	8.0	81.8
4	19	0.47	0.4	2.10	102.5	721.4	2.6	8.0	323.2
5	19	0.53	0.5	3.50	84.4	996.1	4.0	6.0	38.8
6	21	0.46	0.5	1.72	168.8	544.2	2.9	5.0	391.4
7	21	0.39	1.0	2.10	35.4	709.8	4.0	10.0	221.4
8	21	0.59	1.1	0.74	59.3	550.8	6.0	8.0	370.2
9	22	0.85	1.0	0.35	178.2	300.1	5.0	10.0	354.3
10	23	1.20	0.3	0.24	150.8	188.7	2.5	7.0	144.7
11	23	0.79	0.5	0.20	152.2	684.5	3.0	4.0	75.4
12	23	1.37	1.0	0.22	377.9	435.1	9.0	15.0	410.6
13	24	1.92	0.4	0.17	108.3	825.2	2.9	7.0	94.6
14	25	0.86	0.6	2.70	266.1	439.2	3.0	10.0	297.8
15	25	N.D.	0.7	11.2	141.5	661.9	3.7	10.0	94.7
16	25	N.D.	1.2	5.70	310.4	226.3	6.0	12.0	376.4
17	26	1.30	0.5	0.66	217.6	608.2	3.0	14.0	112.9
18	26	1.72	0.6	0.58	42.4	118.3	N.D.	5.6	173.5
19	26	1.30	1.1	0.40	227.0	298.7	8.0	9.0	110.1
20	27	1.20	0.4	0.40	220.3	209.8	2.9	10.0	133.0
21	27	1.20	0.9	0.55	34.6	602.9	4.0	30.0	111.9
22	27	N.D.	1.1	1.70	318.8	399.4	6.0	13.0	117.7
23	30	2.20	N.D.	3.75	80.2	874.0	2.4	2.4	34.6
24	34	0.83	0.6	4.20	100.0	880.8	3.8	14.0	26.7
25	36	0.97	0.3	4.10	734.6	907.4	3.0	7.0	88.1
26	40	1.89	0.6	0.91	92.1	497.4	6.0	8.0	405.0
27	44	1.77	0.8	0.99	120.4	336.5	4.9	8.0	94.1
28	45	2.40	0.6	8.78	134.3	781.1	4.0	5.0	48.7
29	45	1.99	0.8	6.58	73.3	397.3	4.0	6.0	122.9

N.D.=Not Detected

Table 2. Comparative average metal concentrations($\pm$ SD) in unwashed and washed hair samples

Metal	Concentration(μg/g,dry weight)		Ratio(a/b)
	Unwashed(a)	Washed(b)	
As	1.17±0.596	1.0±0.437	1.17
Co	0.71±0.30	0.66±0.480	1.07
Hg	2.37±2.73	1.93±0.791	1.22
K	171.9±138.8	158.9±89.60	1.07
Na	533.6±240.1	527.0±220.9	1.01
Ni	4.34±1.69	3.76±1.11	1.15
Pb	9.55±5.11	5.6±2.93	1.70
Zn	175.62±129.2	169.8±110.10	1.0

Table 3. Metal-to-metal correlation coefficient matrix for washed hair

	As	Co	Hg	K	Na	Ni	Pb	Zn
As	1							
Co	-0.159	1						
Hg	0.310	0.015	1					
K	-0.099	-0.034	0.056	1				
Na	-0.067	-0.332	0.329	0.008	1			
Ni	0.040	0.750	-0.164	0.156	-0.387	1		
Pb	-0.167	0.324	-0.162	0.020	-0.083	0.279	1	
Zn	-0.082	0.308	-0.222	0.089	-0.328	0.388	0.07	1

No viable correlation was found to exist between any pair of metals, in the washed hair samples, except for a Ni-Co correlation (r=0.750), signifying a strong correlation between an essential and a non-essential metal. All other observed positive correlations were not strong enough to validate a further metal-to-metal dependence study. The multiple-metal regression analysis(Table 4) showed some strong metal concentration dependence on the endogenous character of hair. For instance, the concentration variation of a given metal in hair with respect to another metal was found to be maximum for Zn-Ni and Zn-Co pair, with respective slope values of 30.15 and 130.25. However,a comparably strong interdependence between Hg and Na was not understandable on the basis of the present data.

Table 4. Multiple-metal linear regression analysis data

[Co]	=	-0.088	[As]	+	0.078
[Hg]	=	1.123	[As]	+	0.640
[K]	=	-23.74	[As]	+	191.76
[Na]	=	-27.23	[As]	+	582.01
[Ni]	=	0.115	[As]	+	4.09
[Pb]	=	-1.52	[As]	+	11.08
[Zn]	=	-60.84	[As]	+	250.4
[Hg]	=	0.138	[Co]	+	2.22
[K]	=	-15.87	[Co]	+	185.88
[Na]	=	-256.3	[Co]	+	703.20
[Ni]	=	4.27	[Co]	+	1.27
[Pb]	=	5.34	[Co]	+	6.02
[Zn]	=	130.25	[Co]	+	88.32
[K]	=	2.85	[Hg]	+	164.83
[Na]	=	28.93	[Hg]	+	465.10
[Ni]	=	-0.099	[Hg]	+	4.58
[Pb]	=	-0.304	[Hg]	+	10.27
[Zn]	=	-10.51	[Hg]	+	200.52
[Na]	=	0.014	[K]	+	531.15
[Ni]	=	0.002	[K]	+	4.00
[Pb]	=	0.001	[K]	+	9.42
[Zn]	=	0.083	[K]	+	161.47
[Ni]	=	-0.003	[Na]	+	5.88
[Pb]	=	-0.002	[Na]	+	10.49
[Zn]	=	-0.176	[Na]	+	269.78
[Pb]	=	0.867	[Ni]	+	5.92
[Zn]	=	30.15	[Ni]	+	50.06
[Zn]	=	1.764	[Pb]	+	158.79

The levels of industrial metals (Fe, Cr, Cd, Al, Cu) were found, in general, on the higher side compared with the other metals, irrespective of the age of workers. It could be inferred that the donors, exposed occupationally, drew their exogenous share of the metals from their environment(Jervis,1977). Thus the individual variability in levels of the metals in the hair of the donors working at various places could be considered to arise from the effect of the environment on an individual's physiological system, irrespective of the working place.

The regression equations (Table 5)exhibited a strong mutual dependence of As, Pb and Zn in washed and unwashed hair. The strongest positive correlation was found for Pb and Zn ($r=1.000$, $p=0.001$). This indicated that both Pb and Zn were corelated in the washed and unwashed hair, a fact further supported by the comparison of averages based on t-test.

Table 5. Regression equations and correlation coefficients for various metals in washed(w) and unwashed(u) hair samples

Regression equation	Correlation coefficient
$[As]_w = 12.5\ [As]_u - 13.75$	0.500
$[Co]_w = -0.25\ [Co]_u + 0.84$	-0.693
$[Hg]_w = -0.50\ [Hg]_u + 3.12$	-0.500
$[K\ ]_w = -0.50\ [K\ ]_u + 244.6$	-0.500
$[Na]_w = 1.00\ [Na]_u - 5.60$	0.500
$[Pb]_w = 1.00\ [Pb]_u - 3.95$	1.000
$[Zn]_w = 1.00\ [Zn]_u - 5.80$	1.000
$[Ni]_w = 0.50\ [Ni]_u + 1.59$	0.500

Table 6. Results of t-Test analysis at p = 0.05

Metal	Cases	Mean	S.D.	t-Value	p	Result
Zn	1-29 1-8	175.62 169.75	50.17	0.1171	0.9075	Non-sig.
Pb	1-29 1-8	9.55 5.61	1.90	2.0709	0.0458	Sig.
Ni	2-29 1-8	4.34 3.76	0.637	0.9016	0.3738	Non-sig.
Na	1-29 1-8	533.60 527.50	94.41	0.0646	0.9489	Non-sig.
K	1-29 1-8	171.37 158.25	52.11	0.2518	0.8027	Non-sig.
Hg	1-29 1-8	2.367 1.935	0.579	0.7463	0.4605	Non-sig.
Co	1-29 1-8	0.710 0.660	0.1405	0.3303	0.7432	Non-sig.
As	2-29 1-8	1.170 1.00	0.2291	0.7425	0.4634	Non-sig.

The data in Table 6 showed that Pb in the washed and unwashed hair was significantly the same. Considering the limitation of restricted number of samples in the present study, especially with regard to the application of the t-test, it was hard to see whether any other metal also had identical role in the two types of hair. The F-test analysis showed a positive significance of only Hg in the two types of hair ($F=11.85$; $p=0.0024$; result:significant).

The present study evidenced a typical metropolitan exposure of occupational workers to trace metals. The present data are in good agreement with the reported data for scalp hair of donors in densly populated areas of the world(Imahori et al.1979;Ahmad 1991;IAEA/RL/50 1976). The study also revealed a good nutritional status of donors measured as a function of Na and K levels in hair. The industrial metal levels were in general high in the hair of occupationally exposed workers as compared with adults of the same age group, the present levels of As, Hg and Pb were found to be higher than those reported earlier (Qureshi et al. 1982). The present investigation therefore calls for a strict enforcement of regulations warranting a clean working environment. Further work in relation to comparative evaluation of urban/non-urban working sites would be more informative to ensure a better metal pollution control programme for such workplaces.

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