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Trace Elements in Human Hair: An International Comparison

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Distribution of trace elements in the natural environment has become a subject of intense interest in the past few years (Kothny 1973). Toxicological (Goyer and Mehlman 1977), clinical (Brown and Savory 1983), and environmental and/or occupational exposure aspects of the toxic heavy metals towards human beings have been investigated. Hilderbrand and White (1974) and Flynn (1977) have advocated the use of human hair as an index to evaluate the environmental exposure of humans by toxic trace metals. Specific studies for individual trace elements in human hair further reveal the usefulness of the easily accessible biochemical sample; concentrations and distribution of toxic trace elements like mercury (Nord et al. 1973; Jakubezak 1974), lead (Petering et al. 1973; Reeves et al. 1975; Chattopadhyay et al. 1977; Wibowo et al. 1980), heavy metals (Harrison et al. 1969; Briggs et al. 1972; Herber et al. 1983) in hair have been determined to evaluate the levels of environmental exposures.

Hair as a biological tissue is unique in the sense that it serves as an accumulator for trace elements, and in addition, it is formed in relatively short period of time and remains isolated from the metabolic events in the human body. During the growth cycle the hair after an initial surge of activity (0.2 - 0.5 mm/day) is expelled from the skin into almost completely isolated setting (Hopps 1977). The minerals and the metallic contents incorporated in the growth period no longer remain in dynamic equilibrium with the rest of the body. Their concentration profiles apparently serve as indicators as regards status of trace elements in an individual at a particular and specific time period. Trace elements distribution in human hair thus assumes a particular significance since such data remain pertinent to prior recent exposure of an individual to toxic elements as has been shown in the studies conducted by Hilderbrand and

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White (1974), and Chattopadhyay et al. (1977). Other biochemical specimens such as blood or urine, where metallic contaminants remain in constant flux and participate in the metabolic activity, remain inadequate in providing the time scaled status of toxic elements in human beings.

Nord et al. (1973) have used mercury contents of human hair in distinguishing between exposed and unexposed population. Perkins and Jarvis (1966) have studied the distribution pattern of 18 trace elements in human hair and found it unique for an individual in much the same as finger prints. Several other studies on trace elements in human hair describe relationship between elemental concentration and sex and age of an individual (Petering et al. 1973; Eads and Lambdin 1973; Reeves et al. 1975; Takagi 1981; and Herber et al. 1983).

In view of the interest in the distribution of trace elements in human hair an international survey was conducted to study their distribution in populations of different origin. Hair samples drawn from North America (U.S.A., Canada), Europe (Poland) and Asia (Japan and India) were analyzed for 21 trace elements. An attempt was also made to observe a correlation, if any, between elemental concentration, age, sex and living habits of the individuals in a particular country.

MATERIALS AND METHODS

The number of donors from the selected locations in North America, Europe and Asia and the distribution of the samples according to sex of the participant are indicated in Table 1. The age of the Japanese participants ranged from 2 - 80 years, while contributors from India, Poland, Canada and U.S.A. were essentially adults in 30 - 60 years age group. The hair sample in each case was procured by normal cutting and collected with care to avoid any external contamination, and sealed in a clean plastic bag immediately after collection. In addition each donor was asked to complete a personal questionnaire describing his age, sex, domicile, general health, occupation and living habits (vegetarian, non vegetarian, smoker, non smoker, etc.).

Hair sample in each case was cut in the laboratory to about 3mm length to bring it to a uniform size. The sample was then washed with acetone, thrice with distilled water and finally once again with acetone and dried at room temperature before analysis.

A 2g portion of the dried sample was placed in a clean flask along with 10 mL conc. HNO_3 and 2 mL $HClO_4$ and

Table 1. Distribution of hair samples drawn from different populations

Country	Location	Male	Female	Total
Japan	Fukui	228	229	457
India	Bombay and New Delhi	100	155	255
Canada	Moncton	58	34	92
U.S.A.	Scranton	27	28	55
Poland	Poznan	24	22	46
Total		437	468	905

the entire sample wet ashed slowly. Following this the sample was taken up in 0.5N HCl and the volume brought to 20 mL in a standard flask. Trace elements Ca, Mg, P, Na, K, Fe, Cu, Mn, Zn, Cr, Se, Ni, Co, V, Pb, Cd, Al and Sb were analyzed by inductively coupled argon plasma emission spectroscopy using Shimazu ICP-1000 emission spectroscopic analyzer. The instrumental parameters have been described in the instrumental manual supplied by the manufacturer. Five replicate determinations were made in each case and the analytical data thereby represent means of these measurements. The National Bureau of Standards sample SRM-1571 (Bovine liver) was employed as a reference for which unified values of 81-102% were attained for all the elements tested. The coefficient of variation in general ranged between 0.4-4.7% except for Co, V and Se for which larger deviations were noticed approximating to about 10%.

The elements Ca and Mg were also analyzed by flame Atomic Absorption Spectrometry using strontium (500 ppm) as a radiation buffer. The elements Fe, Cu, Mn, Zn, Pb and Cd were similarly analyzed by flame Atomic Absorption. The analytical data were duly corrected through the use of deuterium background correction and other instrumental parameters were adjusted as specified in the users manual for the Atomic Absorption Spectrometer. The elements As, Sn and Se were analyzed through the flameless Atomic Absorption Spectrometry following their hydride generation using $NaBH_4$ reduction method. The National Bureau of Standards sample SRM-1577 was employed as a reference in the atomic absorption determinations. The unified results of 93% and 92.1% were attained for As and Sn while recovery was between 89-101% for the other elements in this case.

The analytical scheme for mercury analysis involved two-stage heating of a 5 mg hair sample in a porcelain boat with a flux of Al_2O_3 (2g), $Ca(OH)_2$ (1g) and Na_2CO_3 (1g). The sample was initially heated to 370°C for 4 min and in the second stage the temperature was raised to 700°C for 6 min with air circulation controlled at 0.5L/min in the Regaku mercury SP MD-A apparatus. The mercury concentration was determined using low voltage mercury tube (253.7 nm) by the flameless atomic absorption approach.

RESULTS AND DISCUSSION

In all 905 hair samples were analyzed for 21 trace elements. The mean concentrations of these are shown in Table 2. At a first glance it is evident that Ca, Mg, P, Na, K, Fe, Cu, Mn, Zn, Se, Pb, and Al occur at significantly higher concentrations compared to the other elements. Among the heavy metals Zn, Cu, Fe, Al and Pb occur in larger amount in decreasing order. Furthermore it is noticed that histograms of Ca, Mg, P, Cu and Zn concentrations are close to normal distribution, while for the toxic elements Hg, Cd, Pb and As, a pattern that follows logarithmic normal distribution, is observed. The other elements show their concentration distribution in between these two groups.

Comparison of the elemental distribution in the hair samples pertaining to a specific country leads to the following general observations:

The Japanese samples show levels of Hg, and Sn for males and Co, Ni, Sb and Hg for females higher than other populations.

The Indian samples show levels of K, Fe, Cr and Al for males and Mg, Se, V, Pb, and As for females higher than other nationals.

The Canadians and Americans show in general higher concentrations of Cd and Cu in the hair samples. The Canadians have higher amounts of Zn and Sb, compared to others. While the same is true for Se, Cd and Mn for the Americans. In the case of females Cu and Mn remain high for both Canadians and Americans. But Se and Sn are higher in Canadian female samples compared to the American female samples and this reverses for Ni and Cd.

The number of samples procured from Poland was low, nevertheless, the trend seems to be that Cu and Cd occur at higher levels in females compared to males. On the other hand Na and K levels tend to be lower for males and females in general.

For the 21 elements analyzed in hair samples a posi-

Table 2. Analytical Data for 21 elements in hair samples from five countries (mean value in ppm).

Element	Canada	U.S.A.	Poland	Japan	India
Ca	452	479	1139	700	895
Mg	64.0	36.1	61.6	127	156
P	118	105	114	151	133
Na	32.6	31.9	3.08	153	17.3
K	9.7	4.84	1.46	12.9	14.1
Fe	18.8	13.6	22.1	15.0	36.0
Cu	63.1	108	9.42	10.7	20.0
Mn	3.2	7.32	0.82	2.4	2.23
Zn	248	124	160	114	211
Se	16.4	21.7	0.35	3.90	10.8
Cr	0.35	0.234	0.27	0.23	1.02
Ni	0.26	1.01	0.52	2.70	0.35
Co	0.043	0.047	0.022	0.18	0.051
V	0.16	0.17	0.056	0.081	0.14
Pb	5.38	5.35	2.52	3.62	13.2
Cd	0.503	0.97	0.31	0.28	0.32
Al	17.4	5.90	7.29	13.3	32.0
Sb	0.86	0.096	0.11	0.67	0.40
Hg	0.93	0.74	0.28	2.2	1.3
Sn	0.29	0.31	0.28	0.39	0.19
As	0.016	0.019	0.022	0.053	0.61

tive correlation ($r = 0.78$ male and $r = 0.74$ female) is observed for Canadian and American samples. Surprisingly female hair samples from India and Japan show a negative correlation ($r = 0.625$).

Age group comparison among the five countries shows that Japanese male samples have higher Pb and Cd contents in the lower age group and this decreases markedly as group age increases. However, the reverse is true for Zn and Mg for the same population.

Samples from India for all age groups show increased concentration for Fe, V and Al while Cu appears to be higher in Canadian and American samples compared to those from India, Japan and Poland.

Female hair samples from Japan show an increase in Ca, Na and Mg with an increase in the group age, while this trend reverses for Pb and Cd.

An attempt was made to establish a correlation between dietary intake of trace elements and their corresponding concentrations in hair samples. The information from the five countries on daily ingestion of trace elements through dietary consumption shows that daily intake in U.S.A. and Canada is more or less similar, while there are some variations in the Japanese diets. Detailed data from India are unavailable, nontheless, it is known that aluminum and iron cooking wares are abundently used in the Indian cuisine. Perhaps this in part may be responsable for increased Fe and Al concentrations in the hair samples from India. Dietary route alone can not be invoked on the other hand to account for increased Cu, and Se contents in Canadian and American hair samples. Intercountry comparison of the priority toxic elements i.e. Hg, Pb, Cd and As does not reveal any definite trend based on dietary consideration alone and the variations noticed probably result more from environmental effects. However, a comparison of the mercury hair content of heavy fish eating and little fish eating groups for both male and female populations reveals that Japanese have significantly higher mercury concentration. This may result due to the cumulative effect of dietary and environmental factors.

No significant difference was noticed for trace elements in hair from smoking and non smoking populations.

Differences in trace element contents in hair were noticed for samples receiving greater frequency of shampooing (3-7 times/week) against normal shampooing (1-2 times/week). For the Indian male samples Se, Co, and As contents were found to decrease with increased shampooing frequency while the same was noticed for Ca for Canadian, American and Polish samples. This trend was observed for Hg only for the Japanese female samples.

Some differences in trace element contents were noticed for prewashed and unwashed hair samples. These differences were more noticable for the Indian samples. The Ca, Mg, K, Fe, V, and Al contents were significantly higher for the unwashed samples. These data suggest the importance of the environmental factors. However, for the elements P, Cu, Mn, Zn, Cr, Se, and Co no significant differences were observed for washed or unwashed sample, which indicates that these elements are bound tightly to the hair structure and in fact become an intergral part of the sample during its growth cycle.

For the female samples those receiving frequent permanent wave treatment in general showed lower Hg content, while those being colored or dyed tended to show a higher concentration of Mg and Mn.

This preliminary survey, though not conclusive, does suggest that trace element analysis in hair can be useful in studying the impact of environmental and dietary factors on humans in general.

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