Bull. Environ. Contam. Toxicol. (1990) 45:139-148

Bulletin of Environmental Contamination and Toxicology

Lead and Cadmium in Human Hair: A Comparison Among Four Countries

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Concern over the health hazards caused by lead and cadmium in the environment has been emphasized by several investigators (see for e.g. Bryce-Smith and Stephens 1980; Nriagu 1984). It has been suggested that due to anthropogenic input in active pools in the environment there is a net built up of metals in the living biomass including man (Elias 1975). Heavy metal content of human hair has been used for some time as an index to assess environmental and occupational exposure to toxic metals (Hilderband and white 1974; Takagi et al. 1986). Kapito et al. (1967) proposed hair lead analysis for diagnosis of plumbism.

Unlike other biological specimens (e.g. the blood and urine) which indicate recent exposure, trace metal content of hair correlates with body stores, especially of bones, and reflects for each individual, specific factors of genetical and environmental origins (Valkovic 1977; Limic and Valkovic 1986). Moreover, human hair samples are readily donated, easily sampled and stored, and more remarkably they tend to accumulate trace metals to a relatively greater extent than many other body tissue, thus rendering chemical analyses much easier (Lenihan 1978). It has been estimated that in a healthy person, the concentration of lead in scalp hair may be 2-5 times higher than in bone, 10-50 times greater than in blood and from 100-500 times higher than in urine (Valkovic 1977; Hansen 1981).

Hair growth begins in the hair follicle where it is formed from the circulating blood and other body fluids. This is the period of time where lead, cadmium and other contaminants in human fluids enter the hair structure endogenously. As a result of continuous abstraction and growth in the follicle,

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the hair is finally extruded as a fiber above the skin where it is completely isolated from the metabolic events inside the body; thus providing a unique testimony for the prevalent levels of contaminants in the body fluids at the time of its genesis. Moreover, environmental as well as metabolic temporal changes of many elements are permanently recorded along the longitudinal axis of the hair fiber.

Reports in the literature on lead and cadmium in hair in the general population are extensive (see for e.g. Eads and Lambdin 1973; Bates and Doyer 1965; Hammer et al. 1971 and Lenihan 1978). Fergusson et al. (1981) reported lead in hair levels among occupationally exposed persons and their families. Petering et al. (1973) suggested the normal levels of lead and cadmium in hair for normal non toxic exposure. Takagi et al. (1986) made a comperative study between North American, European and Asian levels.

In this paper we present results of a survey of lead and cadmium in human hair among four suburban university communities from four countries, two European (England & West Germany), one Asian (Saudi Arabia) and one African (Sudan). Hair samples were analyzed for lead and cadmium in order to compare levels and distribution between populations of different ethnic background and geographical location. An attempt was made to study correlations, if any, between levels of lead or cadmium and smoking habits or sex.

MATERIALS AND METHODS

The number of samples and sampling locations for each of the study groups and the distribution of samples according to sex and smoking habits for the English and German groups are shown in Table 1. The English hair samples were obtained in Hillingdon borough, in the suburb of London and mostly came from students and staff at Brunel University, Uxbridge. The Saudi Arabian samples were collected at the campus of KFUPM in Dhahran. The Sudanese samples were mostly from the University of Khartoum campus and the German samples were obtained from a university community in Buchem. The majority of samples studied represent adults in 20-50 years age group and were obtained from a normal hair cut with the assistance of a number of hairdressers and barbers. Care was taken to avoid any external contamination during collection. Information with regard to sex, age and smoking habits were provided by the donors. Samples were stored in clean plastic bags prior to analysis.

Table 1. Distribution of hair samples according to country, sex and smoking habit.

Country	Location	Males	Females	Smokers	Total
England	Hillingdon/ London	39	27	20	66
S.Arabia	Dhahran	22	-	-	22
Sudan	Khartoum	59	-	30	59
W.Germany	Buchem	20	11	14	31
	Total	140	38	64	178

All the glassware and plastic-ware used for storage washing and analysis of hair samples in this investigation had been acid cleaned by soaking for at least 24 hours in concentrated HNO_3 and rinsed twice with double distilled water.

Hair samples (1-5g) were cleaned before analysis with successive portions of acetone and distilled water according to the procedure of Bagliano (1981). The samples were then dried at room temperature on a clean bench for one day and subsequently dryed in an oven at 110°C for 2 hours in order to determine the moisture content of hair which was subsequently used to refer all concentrations to a dryed sample basis. The mean hair moisture content was found to be $13\pm0.3\%$. Approximately 1-2g sub-samples were digested for analysis.

Four different methods for the extraction of metals in hair have been reported in the literature (Fergusson et al.1981; Bagliano et al. 1981). These methods are: wet ashing using HNO_3/H_2O_2 mixture, dry ashing at 450°C, wet ashing using HNO_3/H_2SO_4 mixture and wet ashing using $HNO_3/HClO_4$. In the present study we have scrutinized the four procedures before adopting a standard method for digestion. Four sets of hair subsamples were treated by the different digestion techniques and analyzed for Pb and Cd. F variance tests showed that the 4 methods gave significantly different results for Pb ($F=6.4$, $p=0.005$) and no differences for Cd. The HNO_3/H_2O_2 method and the high temperature ashing procedures appear to give comparable results for Pb which are constantly higher than the results obtained by the other two methods. The HNO_3/H_2SO_4 extraction technique was found to be relatively the poorest of the 4 methods of extraction for Pb.

The English, German and Sudanese samples were analyzed by acetylene air flame atomic absorption (FAA) procedures using Perkin Elmer atomic absorption spectrophotometer model 303 & according to manual instructions supplied by manufacturer. The Saudi samples were analyzed by both heated graphite furnace atomic absorbtion procedure (HGFAA) using perkin Elmer atomic absorbtion spectrophotometer model 560 & by using Inductively Coupled Argon Plasma emission spectroscopy (ICAPES) using Jarrell Ash ICAP 9000. The instrumental parameters used for analysis have been described in the instrument manuals supplied by the respective manufacturer. In all procedures used, spiked and replicate subsamples were analyzed in order to determine recovery and overall uncertainty in the analysis of Pb and Cd.

The overall average uncertainity in Pb and Cd analysis estimated from the mean coefficient of variation of 20 duplicate analysis were 5% for Pb and 12% for Cd. No significant differences for Pb or Cd were observed between the results obtained by ICAP and HGFAA. Recovery for Pb and Cd for the 3 procedures employed were generally very good and average about 95% for both metals.

RESULTS AND DISCUSSION

In all 178 hair samples were analyzed for Pb and Cd. The ranges and mean concentrations for males, females, smokers, non-smokers and the overall mean concentration for each population are shown in Table 2. Frequency distribution histograms of Pb in hair for each country & the accumulated frequencies for the 4 populations are shown in Fig.1. Similar illustrations for Cd in hair are shown in Fig.2. F-variance and 'Student t' statistics were used to determine if the overall mean levels of Pb or Cd in hair in the 4 populations are significantly different and whether concentrations are affected by sexuality or smoking habits. Least square linear regression analysis between hair Pb and hair Cd were also carried out in order to determine if there is any association between the metals.

The frequency distributions of Pb and Cd in hair (Fig.1 and 2 [Top]) follow a logarithmic normal

Table 2. Ranges and arithmatic mean concentrations and standard errors (in ug/g) of Pb and Cd in hair from England, Saudi Arabia, Sudan and West Germany

	Metal	England	S. Arabia	Sudan	W. Germany
Range	Pb	1.1-48.4	1.5-16.0	2.4-59.7	0-30.1
"	Cd	0-2.9	0-0.77	0-2.6	0-2.1
Males	Pb	9.2±8.5	6.3±3.9	14.1±10.7	7.6±7.0
"	Cd	0.51±0.89	0.19±0.19	0.18±0.43	0.37±0.56
Females	Pb	11.8±8.4	-	-	10.6±5.2
"	Cd	0.45±0.30	-	-	0.56±0.36
Smokers	Pb	11.3±11.3	-	14.7±10.9	9.2±7.4
"	Cd	0.30±0.28	-	0.10±0.22	0.37±0.32
Non-Smokers	Pb	9.6±7.0	-	13.4±11.1	7.3±5.5
"	Cd	0.57±0.82	-	0.24±0.53	0.47±0.60
Overall	Pb	10.2±8.4	6.3±3.9	14.1±10.7	8.2±6.4
	Cd	0.47±0.71	0.19±0.19	0.18±0.43	0.42±0.49

pattern for the 4 populations studied. The accumulated frequencies of Pb and Cd in hair (Fig. 1 and 2 [Bottom]) show clearly the differences between the 4 populations investigated. The English and German Pb or Cd cumulative distributions are similar and overlap each other for up to 60% in case of Pb and for as much as 85% for Cd. The cumulative distributions also indicate that, out of the 4 populations studied, the Sudanese have the highest Pb levels and the Saudi Arabian contained the lowest. The Cd cumulative frequency distributions (Fig.2[Bottom]) show that English and German subjects contain significantly higher Cd in hair levels than Saudi Arabian and Sudanese.

Statistical analysis of the data showed that the overall mean concentrations of Pb or Cd in hair for the 4 populations are significantly different ($F=5.43$, $p=.001$ for Pb; $F=4.12$, $p=.007$ for Cd). The Sudanese population has significantly higher mean Pb in hair level than the Saudi Arabian ($t=4.6$, $p=0.0001$), German ($t=2.97$, $p=0.0004$), and English populations ($t=2.1$, $p=0.04$). Saudi Arabian mean Pb in hair level, on the other hand is significantly lower than the other 3 populations (t between 2.1-4.6,

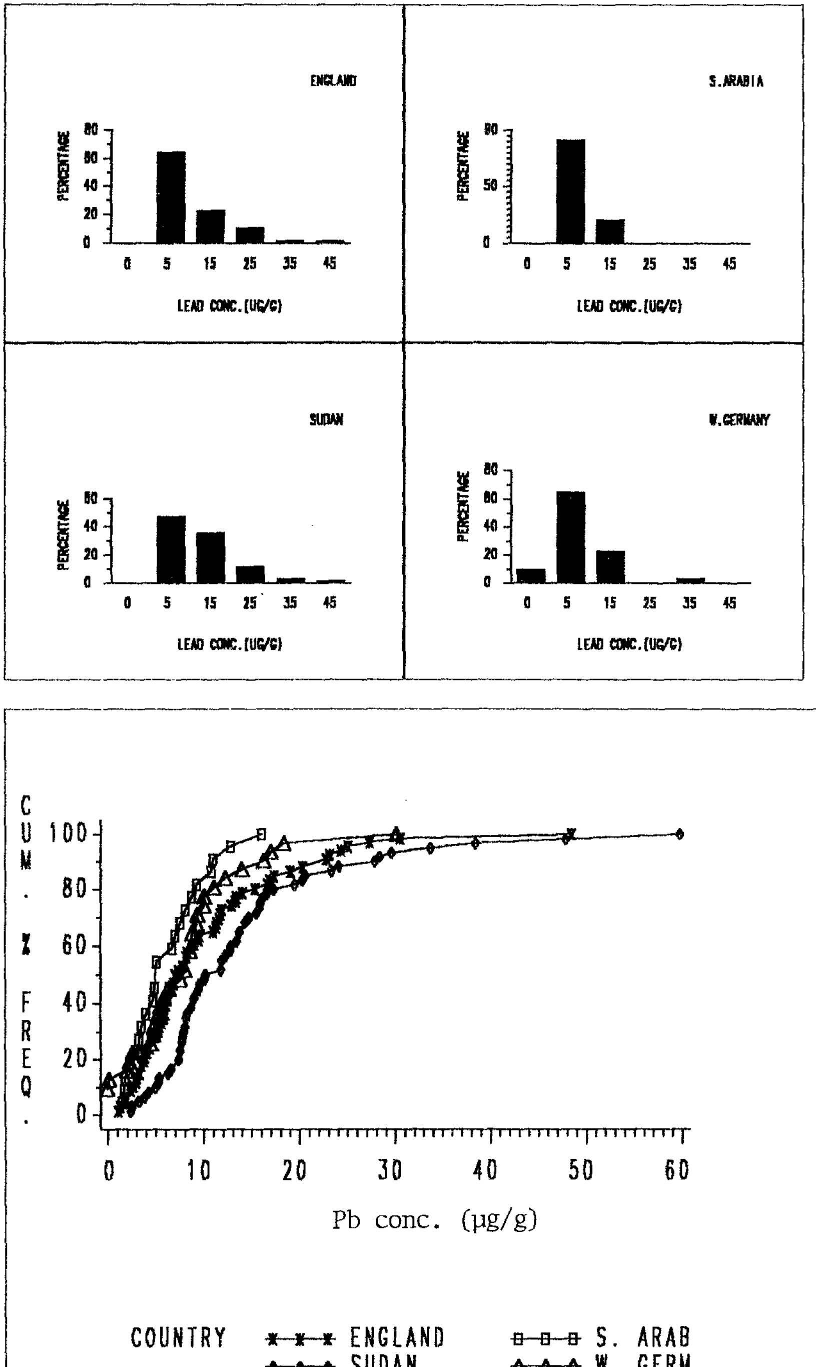

Figure 1. (Top) Frequency distribution of Pb in hair.
(Bottom) Accumulated frequencies.

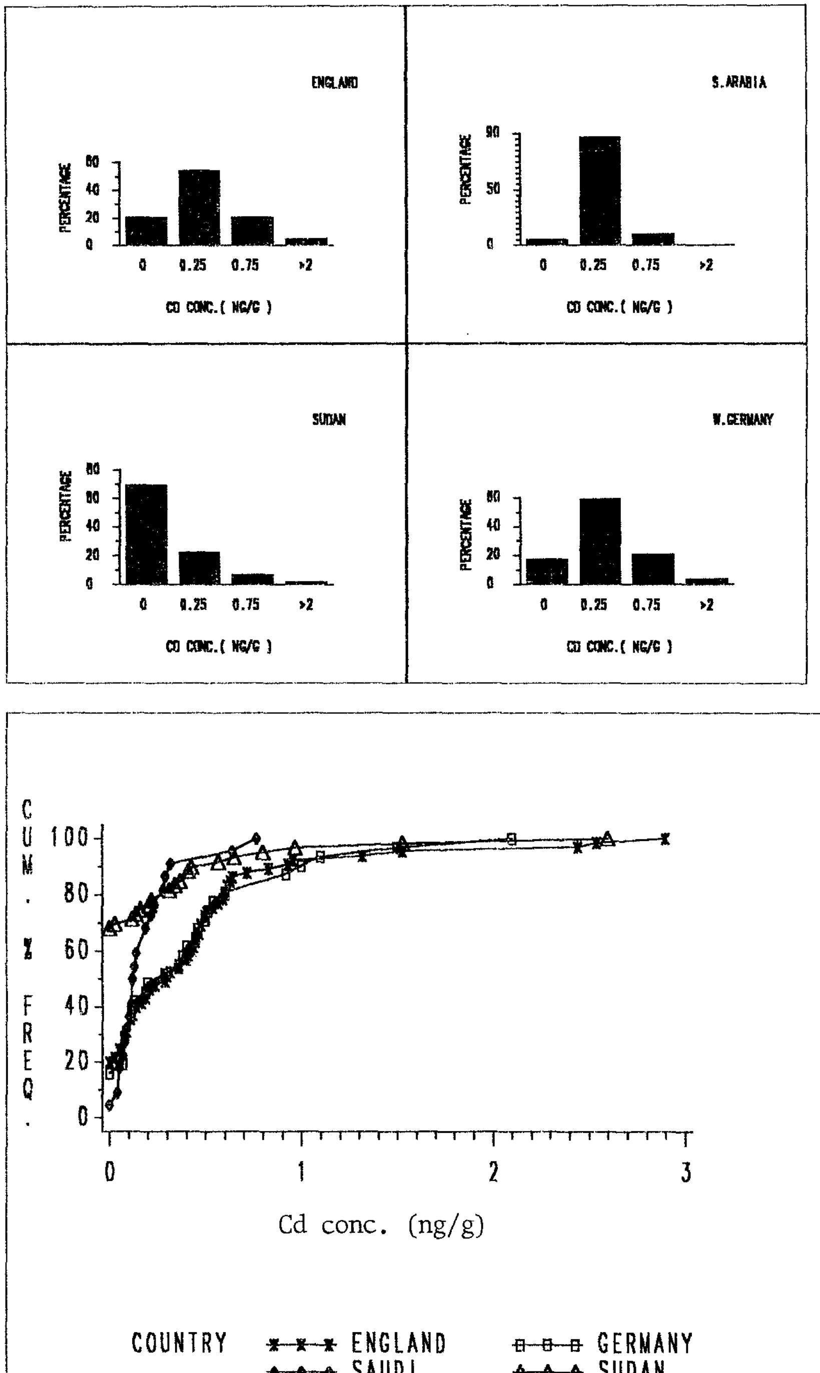

Figure 2. (Top) Frequency distribution of Cd in hair.
(Bottom) Accumulated frequencies.

p=0.04-0.0001). No significant differences were observed between the English & German mean Pb in hair levels. Like Pb, the mean Cd in hair levels of English and German subjects are not significantly different. Both populations, moreover, showed significantly higher Cd in hair levels compared to Saudi Arabian or Sudanese populations (t between 2.42-3.1, p=0.02-0.003). No significant differences were observed between the Saudi and Sudanese levels. Results of F-variance and 'Student t' statistics also showed that there are no significant differences in the Pb or Cd mean hair levels between males and females and between smokers and non-smokers.

The English and German hair samples showed significant positive correlations between Pb and Cd which appear to be enhanced by smoking (p=0.05--p=0.005). Non-smokers showed no significant correlation between the two metals in hair. Also Saudi Arabian and Sudanese samples showed no correlation between hair Pb and hair Cd.

In general, the Pb and Cd levels found in this study are within the ranges reported worldwide for normal occupationally non-exposed populations (Suzuki et al. 1984, Takagi et al. 1986; Hansen 1981). They are lower than the values reported for some industrialized cities in USA (Eads and Lambdin 1973; Bates and Doyer 1965; and Lenihan 1978) and lie within the Pb and Cd ranges suggested by Petering et al. (1973) for normal non-toxic exposure. The English and German Cd in hair levels, however, exceed the normal range of 0.24-0.27 ug/g suggested by Iyengar et al. (1978). The Saudi & Sudanese levels, on the other hand, are below this range. Since Cd is a high technology metal of little or no industrial sources in the Sudan and Saudi Arabia, Cd in hair in these two populations probably reflect the background levels. There is no simple explanation for the relatively high hair Pb observed among the Sudanese population. Since Pb plumbing is common in the Sudan, one possible source for Pb is drinking water. The positive correlation between hair Pb and Cd observed with English and German samples and the lack of correlation in case of Sudanese and Saudi Arabians suggest that there is a common source or, at least, correlated sources for Pb and Cd in England and Germany and separate sources in Saudi Arabia and Sudan. Association between the two metals, also implies that exposure to either of them result in the uptake of the other. Smoking does not significantly affect the levels of Pb or Cd in hair but somehow influences their interelemental relationship.

Acknowledgments. This research was supported by the Research Institute, King Fahd University of Petroleum and Minerals. Part of the work in this paper was carried out at the School of Chemistry, Brunel University, England, helpful comments and suggestions from Dr. A.J Lacey and Dr. D.N. Waters are appreciated.

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Received April 3, 1989; accepted December 12, 1989.