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Human hair analysis in relation to similar environmental and occupational exposure

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ABSTRACT

The aim of this work was to assess the influence of various factors on the elemental composition of the investigated hair samples. The studied population consisted of students of Faculty of Chemistry at Lodz University of Technology and included 95 subjects. The following elements: Co, Cr, Cu, Li, Sr, Pb were determined by inductively coupled plasma time-of-flight mass spectrometry ICP–TOF-MS. The obtained results were elaborated using *Statistica ver. 10.0* software. Statistically significant differences were observed for the content of Cr, Li, Pb and Sr as the impact of sex, and Sr—as the effect of cosmetic treatment. Based on the calculated Spearman correlation coefficients, a statistically significant correlation between the concentration of pairs of metals were found for Pb = f(Co, Cr, Cu); Sr = f(Cu); Li = f(Cr), Cr = f(Li, Pb), Co = f(Pb) and Cu = f(Pb, Sr). A statistically negative correlation was obtained for Sr–Li. In the population two groups were distinguished: males and females; smokers and non-smokers.

1. Introduction

Over the last decades there has been an increasing awareness of environmental and occupational exposure to toxic elements (Kosanovic and Jokanovic, 2011). Exposure to toxic heavy metals may lead to intoxication and may pose a particular threat to the health of humans and all living organisms. Hazardous elements accumulate inside cells, which can result in a number of pathological changes, diseases, or in the case of severe poisoning even death.

Biomonitoring offers the opportunity to analyze people's exposure to different chemicals (Juberg et al., 2008). Environmental biomonitoring may be done using different kinds of body tissues such as blood or urine for acute exposure or hair or nails for longer times exposure (Bencko, 1995; Chojnacka et al., 2005; Iyengar, 1998; Rodushkin and Axelsson, 2000). However, the determination of minerals in blood does not necessarily reflect the current organism status because of homeostatic mechanisms and the fact that urine displays the amounts of elements eliminated from the body. What is more, hair is a highly mineralized tissue, which means that the concentration of elements is higher than in blood or urine (Chojnacka et al., 2010a; Puczkowski and Krupka, 2001). Human hair reflects minerals and chemicals contained in the organism. This means that there is a correlation between the concentration of chemical elements and compounds in hair, and the actual internal levels of those substances in the body. Additionally, the level of concentration of elements in hair is much higher than in blood or urine, which makes it easier to determine (Hać et al., 1997; Puczkowski and Krupka, 2001;Radomska et al., 1991; Srogi, 2005; Szynkowska et al., 2007). The advantages of hair analysis also include: non-invasive sampling, a lack of problems with transport and storage of samples and the ease of removal of contaminants from the hair which is associated with its construction. Hair keratin sheath prevents penetration of exogenous contamination from the environment into hair and also prevents the loss of the components from the inside (Ashraf et al., 1995; Bencko, 1995; Bermejo-Barrera et al., 2002; Chojnacka et al., 2010b, 2006; Iyengar, 1998; Radomska et al., 1991; Rodushkin and Axelsson, 2000). On the other hand, the analysis of human hair presents a few limitations such as a lack of well-defined reference concentration ranges or difficulties in interpreting the results (Szynkowska et al., 2009). Factors like gender, age, cosmetic hair treatment, dietary habits, place of living, lifestyle cause huge differences between the levels of elements in hair. Because there may be some problems with interpreting the

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results, every volunteer should fill in a questionnaire before the analysis (questions about diet, age, gender, etc.) (Chojnacka et al., 2010b).

The analysis of hair was initially used to evaluate exposure to toxic elements (Villain et al., 2004; Keil et al. 2011). In 1875 Casper described the application of hair analysis to detect arsenic. In 1975 Flesh suggested that hair could be applied as a biopsy material to detect trace elements in human organisms (Katz and Chatt, 1988). Since then hair analysis has been widely used, not only in the evaluation of toxic exposure but also in other fields. Human hair is a useful tool which can give a lot of information about the elements stored in the internal organs, their mutual correlations and the mineral and metabolic body status. It is considered a relatively simple screening test, which is mainly used in medicine, toxicology, biomonitoring studies, forensic science as well as in the individual assessment of chemical elements contained in the human body.

The investigation of the mineral status of human organism gives information on the diet, environmental exposure, health problems, medicines or supplements taken. The composition of human hair depends on different factors such as age, sex, cosmetic treatment (coloring, perming, bleaching, frequent washing), dietary and living habits, geographical region and individual physiological differences (Chojnacka et al., 2010b).

According to Paracelsus "The dose makes the poison". It means that it is important to determine the levels of toxic elements as well as the level of bioelements. The lack of essential elements may cause serious physiological disorders however the excess of some of them might be dangerous too. That is why it is so important to control the body's mineral status by determining the concentrations of toxic elements and bioelements. Controlling the correlation ratio between the occurrence of different elements in the body is also of great importance. There is a balance between certain elements which must be maintained in order to correct metabolic and physiological processes (Puczkowski and Krupka, 2001). The deficiency or excess of some elements may be a reflection of serious health problems (Wołowiec et al., 2013).

The aim of this work was to assess the influence of various factors on the elemental composition of the investigated hair samples. The studied population consists of students of Faculty of Chemistry at Lodz University of Technology so they represent a group of people with similar environmental and occupational exposure. In the population two groups were distinguished: males and females; smokers and non-smokers. The group of females was divided according to hair treatment into two groups: women with natural hair, and women with dyed hair. The obtained results were elaborated using statistical methods and compared with the literature data for the groups of young people of similar age.

2. Materials and methods

The research was carried out on ninety five volunteers (24 males and 71 females) collected from the population of students (aged 19–25) of Lodz University of Technology in 2012. The population consisted of people who lived in the region of Lodz (central Poland). All of the volunteers underwent similar environmental exposure. The criterion was to choose volunteers who underwent similar occupational and environmental exposure that is why the experimental population consisted of students who study at the same university and live in the region of Lodz for at least 6 months. The volunteers were asked to fill in a detailed questionnaire (containing questions) about their lifestyle, dietary habits, medication, smoking, etc. The dependence of hair content on various factors such as gender, tobacco smoking habits and hair dyeing was examined.

Table 1
Results of analysis of certificate reference material—NCS ZC81002 [μg/g].

Element	Certificate value ± U (μg/g)	Obtained results ± S.D. (μg/g)
Cr	8.740 ± 0.970	8.230 ± 0.120
Li	–	–
Co	0.1530 ± 0.015	0.1500 ± 0.010
Cu	33.600 ± 2.300	32.770 ± 1.450
Sr	8.170 ± 0.690	8.710 ± 0.210
Pb	3.830 ± 0.180	3.900 ± 0.090

U—uncertainty.

2.1. Sampling

Prior to the sample collection washed with shampoo and cosmetically untreated hair was cut from the back of the head as close to the scalp as possible. No additional washing was performed. The place from which the samples were collected is also known as posterior vertex. For this non-invasive operation stainless steel scissors were used. Each sample contained hair from 4 or 5 different locations of the posterior vertex. The length of the hair used for the analysis was approximately 5 cm or less which corresponds to the period of the past 3–4 months of exposure before the samples' collection. The weight of each sample was 0.2–0.3 g. The samples were stored in polyethylene bags.

2.2. Reagents and standard solutions

High purity deionized water—Milli-Q Gradient by Millipore was used throughout the analysis. All reagents used were of trace analytical pure grade. Concentrated nitric acid (65%) used for the digestion procedure was obtained from Baker (Germany). Multi-elemental stock solution ICP MERCK IV containing 1000 ppm solution of all elements was stored in a high-density polyethylene bottle. Stock solution of all elements was obtained from Merck (Germany).

2.3. Analytical methods

The concentration of chosen toxic and essential elements in human hair samples was determined using the inductively coupled plasma time-of-flight mass spectrometry technique ICP–TOF-MS (OptiMass—8000, GBC, Australia). The analytical procedure was verified by the analysis of Certificate Reference Material (CRM) of Human Hair NCS ZC81002 from China National Analysis Center. Table 1 presents the results obtained for CRM. The samples before the elemental analysis were placed in Teflon vessels, solubilized with concentrated nitric acid (Baker) and digested in the microwave oven system Milestone 1200 MEGA (Italy). After digestion samples were diluted to final volume with demineralized water. The obtained by ICP–TOF-MS limits of detection for analyzed elements were as follows Cr—0.3 ng/g; Li—0.18 ng/g, Co—0.2 ng/g; Cu—0.27 ng/g; Sr—0.18 ng/g; Pb—0.08 ng/g.

2.4. Statistical methods

The obtained results were elaborated using the *Statistica ver. 10.0.* software. Descriptive statistics such as means, medians, standard deviations, range and 5–95th percentiles were reported. Normality of distribution of experimental results was assessed by Shapiro–Wilk and Lilliefors tests. Data distribution was found non-normal throughout the results. According to non-normal distribution non-parametric methods were applied. The existence of the statically significant differences in the concentration of analyzed elements in relation to the studied factors was evaluated based on the nonparametric Mann–Whitney *U* test (significance level $p < 0.05$). The Spearman rank correlation coefficients were