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Comparison of Trace Elements in the Hair of Children Inhabiting Areas of Different Environmental Pollution Types

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Abstract

The objective of this study was to assess the relationships between lead, cadmium, zinc, and copper contents in children's head hair, and the level of environmental exposure in the subjects' places of residence. The studied population was a group of 93 children (62 boys and 31 girls), aged 5-16, living in contaminated regions of the Copper Basin Legnica ("Exposed Group"). Control ("Reference Group") consisted of 66 children (35 boys and 31 girls), aged 6-16, inhabiting non-contaminated rural areas of the Wielkopolska region. The studied material was head hair taken from the occipital scalp. The contents of metals in the hair were determined using atomic absorption spectrometry.

It was found that the mean contents of lead and cadmium in the hair were significantly higher in the "Exposed" children (7.16 µgPb/g and 0.44 µgCd/g) versus the "Reference Group" (2.49 µgPb/g and 0.23 RgCd/g).

The mean contents of zinc and copper in the hair were not statistically different between the studied populations. Moreover, some positive and negative correlations between pairs of elements in the hair were found.

Keywords: Hair lead, cadmium, zinc, copper, children, environmental exposure

Introduction

Increasing industrialization and "chemicalization" of every sphere of human activity has created evident disturbances in the natural environment that affect human health. From among thousands of antropogenic chemical compounds present in the air, water and soil, an increased concentration of heavy metals is considered harmful to living organisms. One difficulty in assessing the effects of toxic heavy metals for past and long-term exposure is to find a reliable biological indicator. For example, lead and cadmium in blood are widely used as indices for current exposure [1-3]. A considerable number of studies have revealed that trace element contamination in head hair should better reflect an average of integrated environmental exposure than does blood and/or urine [4-7]. For assessment of past and continuous exposure, hair seems to be more adequate, since it is easy to collect, store and analyze, and the concentration df metals in hair is higher than in blood. Moreover, lead and cadmium remain in blood only briefly and at very low levels [5]. However, some authors [8, 9] are of the opinion that hair is not a good indicator of exposure and deposits of cadmium in the body since the concentration of this metal in hair tissue is not indicative of its level in the critical organ (kidney). In addition, one has to be aware that there are a number of factors influencing element concentration in the hair, such as age, gender, colour of hair, and nutritional and physiological status of a subject [7, 10]. Besides, the possibility of exogenous contamination of hair has led to substantial controversy concerning the reliability of hair metal analysis as a measure of an adsorbed dose [11, 12]. However, despite many drawbacks, hair analysis may be a valuable first screening test for heavy metal contamination, especially for lead, cadmium, arsenic, and mercury [13, 14].

The objective of this study is to assess whether there are relationships between lead, cadmium, zinc, and copper contents in children's head hair and the level of environmental exposure in a subject's milieu.

Materials and Methods

The 93 children (62 boys and 31 girls), aged 5-16, preselected on the basis of elevated blood lead levels ("Exposed Group"), living in the Legnica district (South-West Poland) that is a region polluted with copper emitted from smelter plants, and the 66 children (35 boys and 31 girls), aged 6-16, ("Reference Group"), living far from industrial and traffic contamination, were screened for heavy metal levels using hair as a biopsy material.

Hair samples were taken from the occipital scalp. The analytical procedure included: a careful washing technique (acetone, non-ionic detergent - TRITON 100-X, and rinsed three times with redistilled water), drying at 105°C, weighing, and wet mineralization. The digestion procedure was performed in semi-covered quartz vessels using a mixture of spectra pure concentrated acids (nitric and perchloric, 2:1, v/v, Merck). The vessels were placed in a thermostatic oven (DHN, Poland) equipped with a vacuum fume hood. The temperature program consisted of three steps: 120"C, 150"C and 180°C until complete decomposition of organic matter. After cooling, the digest was transferred to a volumetric flask to 25 ml with redistilled water. The contents of Pb, Cd, Zn, and Cu in the mineralized hair samples were determined using flame atomic absorption spectrometry with deuterium BC (Zeiss AAS-3). The contents of Pb and Cd were analyzed on the basis of the extraction method, applying 2% APDC and MiBK as an organic phase while the contents of Zn and Cα (after appropriate dilution) were determined directly from the mineralizate.

The accuracy of the method was confirmed by simultaneous analysis of 8 samples of certified human hair CRM 397 (Brussels). The mean recovery obtained for Pb, Cd, Zn and Cu was: 88.3%, 90.3%, 94.3% and 86.4%, respectively. Hair element concentrations were expressed as μg/g dry weight. The descriptive statistics for hair metal data included: arithmetic mean (x), standard deviation (SD), geometric mean (gm), median (m), 90^{th} percentile and range. Statistical evaluation of the data has been made by Chi-square test and linear regression at $\alpha = 0.05$.

Table 1. Hair metal distributions (μg/g) in children, dependent on the level of environmental exposure.

Statistical Parameter	Pb ExpG* RG**	Cd ExpG RG	Zn ExpG RG	Cu ExpG Rg
arithmetic mean ± SD	7.16 ± 7.42 2.49 ± 2.56	0.44 ± 0.35 0.23 ± 0.20	180 ± 60 176 ± 56	13.4 ± 6.9 14.8 ± 12.7
geometric mean	4.95 1.69	0.33 0.18	166 166	11.7 11.2
median	5.15 1.72	0.33 0.20	183 189	14.8 12.0
90^{th} - percentile	15.20 5.30	0.88 0.45	239 238	21.1 23.7
range	0.69 – 44.25 0.50 – 12.88	0.10 – 1.50 0.05 – 1.36	19 – 370 59 – 305	1.4 – 43.0 1.0 – 82.9
statistical analysis (Chi-square test)	p < 0.001	p < 0.001	n.s.	n.s.

* ExpG – exposed group ** RG – reference group
n.s. – non significant

Table 2. Statistical evaluation of the hair element/element correlations in the children.

Element/Element	Exposed Group	Reference Group
Pb/Cd	r = 0.42 p < 0.001 Y = 3.2 + 9 X	r = 0.50 p < 0.001 Y = 1.0 + 6.3 X
Pb/Zn	r = -0.36 p < 0.001 Y = 15.2 – 0.004 X	n.s.
Zn/Cu	n.s.	r = 0.27 p < 0.05 Y = 3.4 + 14.0 X

n.s. – non significant

Results and Discussion

Table 1 shows the hair metal distributions dependent on the level of environmental exposure. The levels of lead and cadmium in the children's head hair differed among the studied populations. The mean values for these metals in the hair were statistically higher ($p < 0.001$) in the Exposed group in comparison with the Reference group (lead: x 7.16 μg/g vs. 2.49 μg/g, gm 4.95 μg/g vs. 1.69 μg/g; cadmium: x 0.44 μg/g vs. 0.23 μg/g, gm 0.33 μg/g vs. 0.18 μg/g). This result is not surprising since the Copper Basin Legnica has been considered one of the most polluted regions in Europe. The total emissions of selected metals in the year of the study (1993), expressed in ton per year, were estimated as following: Cu 160, Pb 82, As 7.4, Cd 0.25. Although the relationship between concentration of trace elements in scalp hair and environmental exposure to metals is very complex, it is reported that trace metals alterations in the hair may reflect general community exposure measured in dustfall, household, and soil [14-17]. Our study confirm the observation that the location contribute most of variance of the lead and cadmium levels in the children's head hair. The level of magnitude for the means of lead and cadmium in the hair of selected children from the Legnica region are in good accordance with those found by Zachwieja et al. [18] for children living in highly industrialized areas of Southern Poland. Similarly, hair lead and cadmium found in the children living in non-contaminated regions of Poland are in agreement with the values reported by Takegi et al. [19] and Kozielec et al. [20].

The mean contents of zinc and copper in the hair (Table 1) are not different between the studied populations. The values are very close to the levels considered normal for healthy individuals [10, 14, 21-22]. This fact implies that hair zinc and copper, as controlled by various factors such as gender, age, nutritional and health status, are not directly related to environmental exposure. There is only little known about the mechanisms by which trace elements are incorporated into hair tissue. According to Bos et al. [23] - five sources of trace elements found in human scalp hair are known: the matrix, serum, sweat, the epidermis, as well as exogenous sources. Therefore, there is a problem concerning how to differentiate a hair element taken directly or indirectly from the body and those originating from external sources. Despite this uncertainty, hair zinc and/or copper have been often used for diagnostic purposes, as indices of their body status in animals and humans [24] as well as for detecting certain diseases [22]. However, the utilization of hair analysis for these purposes remains the object of much conflict and controversy. In the opinion of Dorea and Paine [25-26] there seem to be no real evidence that hair zinc and/or copper is a valid index of nutritional status in children. A comparative analysis of hair metals may not reveal deeper relationships between trace element concentrations that vary dependently on internal and external factors. It is supposed that several metals may tend to increase or decrease together in hair tissue as a result of different covariates. There is some data in literature concerning this problem; therefore, we grouped (in pairs) hair metal concentrations in order to find any possible correlations. Table 2 shows the cases where these correlations are statistically significant. Having done this, we found that despite variable environmental exposure, there is a statistically significant positive correlation ($r = 0.42$-0.50, $p < 0.001$) between lead and cadmium in the hair of children, which may suggest a common external source of these metals. A similar lead/cadmium relationship in hair is also reported by Wibowo et al. [14] and Zachwieja et al. [27]. A weak negative lead/zinc correlation in hair ($r = -0.36$, $p < 0.001$) was shown only in children living in the polluted regions, which seems to reflect a well known physiological antagonism of these elements. However, a zinc/copper positive correlation ($r = 0.27$, $p < 0.05$) found only in hair of the "Reference Group" is hard to explain.

It should be emphasized that interactions between toxic and essential metals can result in disturbances of processes regulated by these elements, which may lead to a number of pathological states. However, there is no ready explanation how an element content changes in hair tissue with various internal and/or external factors. Presumably, environmental contaminants through synergy and antagonism with bioelements may affect metabolic pathways that results in altered concentration of metals in some body tissues.

The results of this study show that children's head hair may serve as a first biochemical indicator for assessment of total lead and cadmium environmental exposure. The interelement correlations in the hair may imply some early changes in the metabolism induced by increased exposure to toxic metals.

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