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ORIGINAL PAPER

Lead content in hair of students in France, Poland and Belarus*

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Abstract

Lead (Pb), a toxic heavy metal, enters the human body through the digestive system. The hair, an appendage of the skin, plays a vital role in removing lead from the body. The dead part of the hair provides analytical material for assessing the Pb content. Using an original survey questionnaire, the study was conducted on hair samples collected from students in Poland, France and Belarus. The survey questionnaire was prepared in three languages: French, Polish and Russian. The aim was to compare the Pb content in the hair of Polish, French and Belarusian students. These three groups of students reside in countries with different economic development and climate, and have other dietary habits, which should be evident in the study results. Head hair samples of approximately 0.2-0.5g were analysed and prepared according to accepted analytical standards. The Pb content in hair was determined under a scanning electron microscope SEM, with a Hitachi TM-3000 apparatus equipped with an X-ray with an EDS spectrometer for microanalysis. The accuracy of this method was verified using certified reference material (NCS ZC81002 human hair of Chinese production). The abbreviated meta-analysis on the lead concentration in hair performed in different laboratories shows a large scatter of results, preventing their unambiguous comparative interpretation. This study, conducted according to the same methodology, allows for assessing factors relevant to the health assessment of students in France, Poland, and Belarus, such as the lead content of hair. Substantial disparity in the hair Pb content was identified depending on the country of provenance.

Keywords: lead, lead concentration, students' hair

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INTRODUCTION

To ensure the proper functioning of the human body, it is essential to maintain an appropriate concentration of mineral components that support systemic homeostasis. Among various chemical elements some are xenobiotics, for example lead, mercury and cadmium, all of which have exclusively negative effects on health. Therefore, monitoring these elements in the body is crucial.

Lead (Pb) is a toxic heavy metal commonly used in industry and, until recently, was used as an additive in gasoline. Concentrations exceeding 100 mg m^{-3} in the air pose immediate threat to life and health (Charkiewicz, Backstrand 2020). Lead can enter the human body through the digestive, respiratory or integumentary system, potentially leading to chronic and dangerous poisoning (Klotz, Göen 2017). Once in the bloodstream, it can disrupt the function of endocrine glands (Mei et al. 2023). Moreover, lead interacts with essential bioelements, such as calcium, iron and zinc. It can damage the myelin sheaths of neurons, reduce their numbers, disrupt neurotransmission, and impair neuronal growth (Hampton et al. 2023).

Lead contamination in food often reflects contamination of air, water and soil caused by dust, industrial emissions, sewage and waste (Liang et al. 2017). The human body expels lead through various routes, including skin appendages such as hair.

Hair, being permanent and inert dead tissue that does not biodegrade and, unlike blood, is not directly influenced by homeostasis, serves as an excellent analytical material for assessing the mineral content of the entire organism.

MATERIALS AND METHODS

The study focused on the analysis of lead (Pb) concentration in hair samples. Hair samples, approximately 0.2-0.5 g in weight, were meticulously collected from six distinct areas of the scalp, ensuring that the hair was cut as close to the skin as possible. Prior to sample collection, participants were instructed to complete the questionnaire to identify the sample. Dyed hair or hair subjected to other cosmetic treatments was excluded from the study to ensure the integrity of the results.

The processing of hair samples followed a stringent protocol, wherein the samples were degreased using $CHCL_3$ spectrally pure, air-dried on filter paper, subjected to $(CH_3)_2CO$ spectrally pure rinsing, and dried again. The determination of Pb concentration was conducted with the use of a scanning electron microscope (SEM), a Hitachi TM-3000, coupled with an energy-dispersive X-ray spectroscopy (EDS) spectrometer for microanalysis in the laboratory of John Paul II University in Biała Podlaska. The validity of this methodology was reinforced through comparison with certified reference material, notably NCS ZC81002, human hair sourced from China.

For each sample analysed, arithmetic means were computed based on the gathered results, and the Pb content was subsequently converted to weight values in reference to the standard sample. The statistical data analysis was executed using the Statistica v. 10.0 PL software alongside Microsoft Office 2010. The percentage of selected responses was calculated for questions assessed on a nominal scale.

In contrast, for the quantitative scale, arithmetic means ($\bar{x}$), minimum (x_{min}) and maximum (x_{max}) values, standard deviation (SD), standard error (SE), median (Me) and lower quartile (Q1) and upper quartile (Q3) were presented.

To ascertain the most appropriate statistical tests for comparing the studied parameters, consideration of normality was undertaken via the Shapiro-Wilk test. Given the deviations identified from normal distribution and the observed high standard deviations and ranges, the analysis of the Pb content was carried out using nonparametric tests, specifically the Mann-Whitney *U* test and the Kruskal-Wallis test, supplemented by the Kruskal-Wallis *post hoc* test for multiple comparisons. The interpretative results were graphically represented using medians, thereby facilitating a clearer understanding of the distribution of Pb concentrations within the samples studied. A statistically significant difference was identified at $p<0.05$.

RESULTS AND DISCUSSION

A total of 121 individuals aged 19 to 45 participated in the study. Researchers examined a group comprised of French students from the Medical Education Centre in Niort, Polish students from John Paul II University in Biała Podlaska, and Belarusian students from Yanka Kupala State University of Grodno. The majority of participants were Polish students (41%), women (65%), and urban residents (72%).

When analysing the variation of the lead content in the hair of these students based on their country of residence, a statistically significant difference was observed ($p=0.03$). Polish students exhibited higher lead levels (Me=2.7 mg kg^{-1}) compared to students from France, who had lower levels (Me=1.5 mg kg^{-1}) (Figure 1, Table 1).

The use of hair analysis to determine elements as a method for assessing the health parameters of individuals raises several concerns. This is mainly due to the significant discrepancies observed in the results. Various analytical techniques, particularly spectral methods, are currently employed

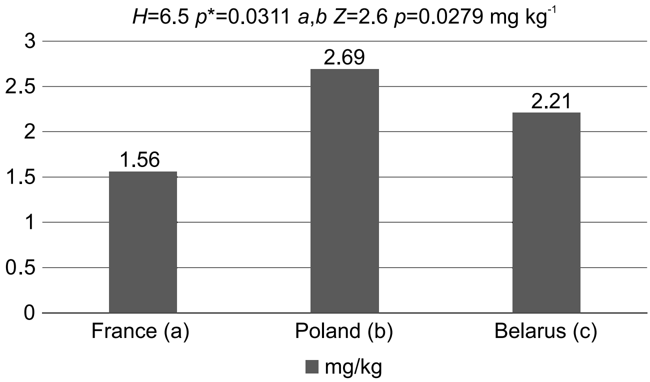

Fig. 1. Variation in Pb content in students' hair, taking into account the country of residence. Country of residence: France (n=39; 32.2%), Poland (n=50; 41.3%), Belarus (n=32; 26.5%); H – value of the Kruskal-Wallis test, F-value of the multiple comparison test (Kruskal-Wallis *post hoc* test), * significant difference at p<0.05

Table 1

Lead content of students' hair, taking into account the country of residence

	$\bar{x}$	x_{min}	x_{max}	SD	SE	Q1	Me	Q3
Lead – Pb (mg kg^{-1})								
France (a)	1,9	0,7	4,5	0,9	0,1	1,4	1,5	2,6
Poland (b)	2,8	0,00	5,9	1,7	0,2	1,6	2,7	4,2
Belarus (c)	2,9	0,7	9,2	2,1	0,4	1,3	2,2	4,3

$\bar{x}$ – arithmetic mean, x_{min} – minimum score, x_{max} – maximum score, SD – standard deviation, SE – standard error, Q1 – lower quartile, M – median, Q3 – upper quartile, * significant difference at p<0.05

for comparative assessments. The range of results is so broad that many researchers have begun to question the reliability of this method. Consequently, in analysing the research findings presented in this paper, a condensed meta-analysis of lead (Pb) determination in hair was utilised, focusing on studies conducted in recent years across different laboratories with similar analytical procedures, as detailed in Table 2.

CONCLUSIONS

The comparative analysis of the lead (Pb) content in the hair of students from three European countries, tested using a consistent method, reveals significant variations.

Additionally, a meta-analysis of findings from studies conducted by various researchers around the world, utilizing spectral methods, undermines a definitive interpretation.

Table 2

Short meta-analysis of Pb in hair

Pb concentration in hair mg kg^{-1}	Determination method	Publication	Cohort location
0,11 - 6,65	Inductively Coupled Plasma Atomic Emission Spectroscopy(ICP-AES)	Xie et al. 2017	Southern China
average 5,86	Inductively Coupled Plasma Atomic Emission Spectroscopy(ICP-AES)	Okorie et al. 2021	California State, USA
1,5 - 40 average 4,7	Inductively Coupled Plasma Atomic Emission Spectroscopy(ICP-AES)	Jursa et al. 2018	the Mid-Ohio Valley, USA
0,284 - 0,829	Inductively Coupled Plasma Atomic Emission Spectroscopy(ICP-AES)	Skalny et al. 2021	Moscow, Russia
0,276 - 0,390	Inductively Coupled Plasma Atomic Emission Spectroscopy(ICP-AES)	Qin et al. 2021	Shenzhen, China
4.88	Inductively Coupled Plasma Atomic Emission Spectroscopy(ICP-AES)	Grundler et al. 2021	Bremen, Germany
0,98 - 3,71	Inductively Coupled Plasma Atomic Emission Spectroscopy(ICP-AES)	Jia et al. 2021	Beijing, China
0,226 - 0,528	Inductively Coupled Plasma Atomic Emission Spectroscopy(ICP-AES)	Piñeiro et al. 2021	Cerro de Pasco, Peru
0,81 - 4,58	Inductively Coupled Plasma Atomic Emission Spectroscopy(ICP-AES)	Wu et al. 2018	Taiwan
0,85 - 1,10	Inductively coupled plasma – mass spectrometry/ICP-MS	Levin-Schwartz et al. 2021	province of Brescia, Lombardy, Italy

Author contributions

JK, ZMK – conceptualization; JK, AS – methodology; JK, ZMK – formal analysis; ZMK, JK - writing – original draft preparation; AS – visualization; ZMK – editing. All authors have read and agreed to the published version of the manuscript.

Conflicts of interest

The authors declare no conflict of interest.

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