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Quantitative Analysis of Heavy Metals in a Hair Sample with the ICP-MS: A Case Report

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Abstract

Background: Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) is a type of mass spectrometry that uses an inductively coupled plasma to determine how much of a specific element is in the material analyzed. It is a highly sensitive and specific quantitative analysis, when the concentration of each element is determined by comparing the counts measured for a selected isotope to an external calibration curve that was generated for that element.

Case Report: The aim of the study is to determine the concentration of each chemical element with ICP-MS in a hair sample of a 25-year-old woman (non-smoker, without a previously diagnosed chronic disease). The research was carried out in the UNILAB laboratory at the University "Goce Delcev"-Stip by the method of ICP-MS, Agilent7500.

Conclusion: We observed low concentration of: Cu, Zn, Ge, Se, B, Fe, Na, K, Rb, Cd, Hg, Tl, Pb, Be, Ag, Sb, Bi and U and high concentration of: Mg, Ca, S, V, Cr, Mo, Mn, Co, Li, Sr, Al Ni As and Ba. The proposed ICP-MS method for analysis of multiple chemical elements is a non-invasive method of investigation and it can be employed in routine analysis, which can extend the use of hair analysis for therapy, occupational, nutritional, and toxicological controls. Therefore, the method itself can help health professionals in identifying and detecting certain toxic elements in the body and perform early diagnosis of certain diseases.

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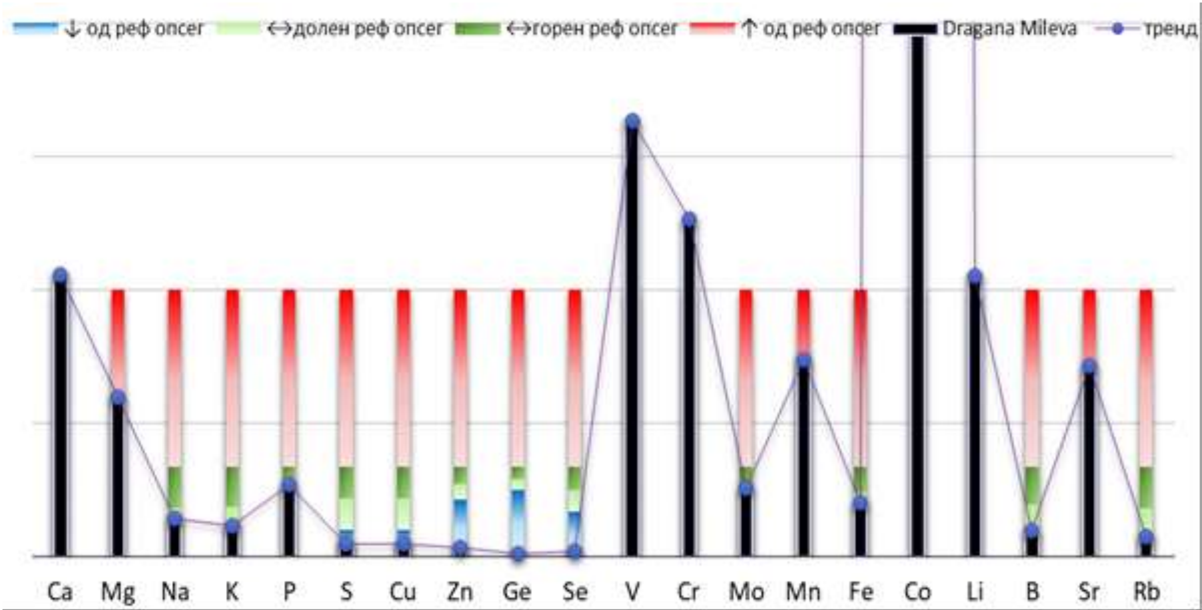
Keywords: Inductively Coupled Plasma-Mass Spectrometry (ICP-MS), heavy metals, hair, biomonitoring

INTRODUCTION

Determination, i.e., detection of the presence of heavy metals in various biological samples is of great importance for the organism, because the increased concentration or presence of certain heavy metals in the body can cause some pathophysiological changes in the tissues themselves (1-5). Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) is a method used to quantify the presence of heavy metals in each biological sample and it is highly sensitive and specific for analysis of multiple chemical elements. It also allows the analysis of isotopes with a low limit of detection for multiple elements in concentration from ppb (part of billion) to ppt (part of trillion). The Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) method uses a high-frequency inductively coupled plasma as ionization source and a mass Spectrometer as mass/charge filter device. It is ideal for the elemental analysis of sample solutions, where the lowest detection limits are demanded. Due to the increase in the number of analyzed samples, analyzed elements and detection limits in recent years, the ICP Mass Spectrometer has become highly regarded for its speed, accuracy, and performance (6). The aim of the study is to emphasize the importance and significance of ICP-MS method as a powerful alternative to the usual bioanalytical methods. This approach extends the detection or determination of concentrations of chemical elements as biomarkers and offers the possibility of detailed analysis of the researched biological sample, in our case, hair.

CASE REPORT

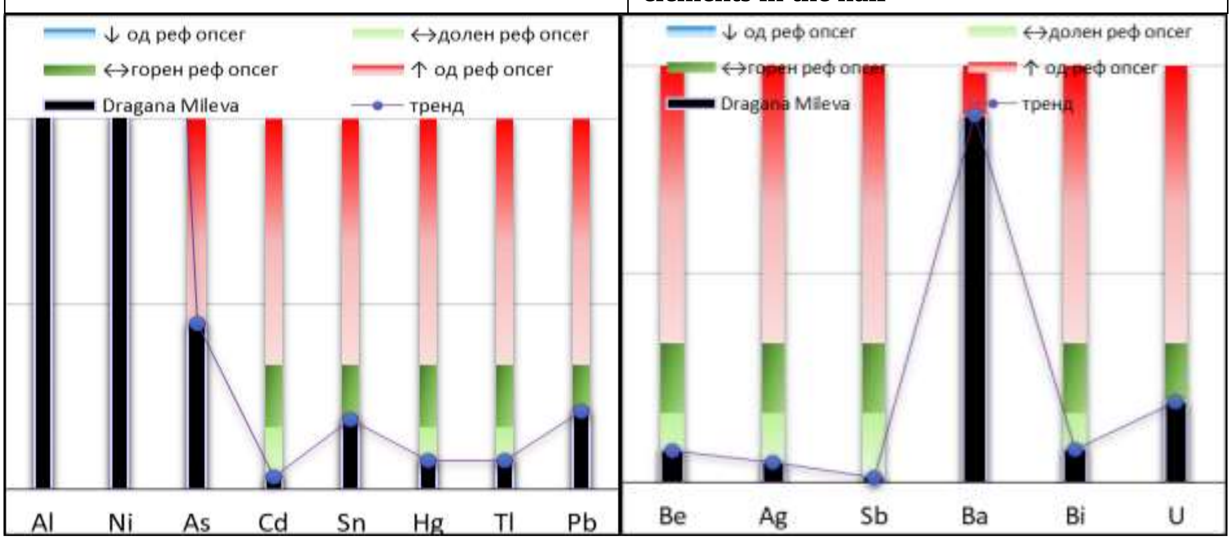
The research was carried out in the laboratory of UNILAB at the University "Goce Delchev" - Stip. More than 30 elements present in a hair sample were analyzed (both macro and micro-essential and toxic elements) (Figure 1 and Figure 2). The respondent is a volunteer, a 25-year-old woman (non-smoking woman with no previously diagnosed chronic disease). The analysis was made due to the respondent's interest in the state of toxic elements in her own organism and accordance with ethical standards, with the consent of the respondent and accordance with the Declaration of Helsinki. After the collection of approximately 0,5g of human hair from the nape of the neck using stainless steel scissors (only the first 3-4 cm closest to the scalp were used), hair samples were performed without treatment (washing) in a laboratory with organic solvents (according to the International Atomic Energy Agencies recommended procedure (7,8). The hair was mineralized (dissolved) with a combination of 5 ml nitric acid and 2 ml hydrogen peroxide in a closed system – laboratory microwave, at constant temperature and pressure, and in the resulting solution were subsequently read the contents of the exanimated elements by the method of ICP-MS, Agilent7500.



Ca	Mg	Na	K	P	S	Cu	Zn	Ge	Se	V	Cr	Mo	Mn	Fe	Co	Li	B	Sr	Rb
237 9	214. 9	107	26	177. 5	393 225	5.2	21.7	0.00 1	0.06	0.32	2.5	0.04	1.33	9.6	6.2	0.63	0.44	16.3	0.04
↑	↑	↔	↔	↔	↓	↓	↓	↓	↓	↑	↑	↔	↑	↔	↑	↑	↓	↑	↔

Figure 1. Relative content of essential macro and microelements in hair in terms of % reference bands and absolute content of certain elements in mg/kg.

1. Relative content of toxic elements in the hair	**2. Relative content of potentially toxic elements in the hair**



Al	**Ni**	**As**	**Cd**	**Sn**	**Hg**	**Tl**	**Pb**	**Be**	**Ag**	**Sb**	**Ba**	**Bi**	**U**
13.6	**2.7**	**0.080**	**0.005**	**0.17**	**0.1**	**0.000**	**0.50**	**0.005**	**0.02**	**0.002**	**5.3**	**0.14**	**0.03**
↑	↑	↑	↔	↔	↔	↔	↔	↔	↔	↔	↑	↔	↔

Figure 2. Relative content of toxic and potentially toxic elements in hair in terms of % reference bands and absolute content of certain elements in mg/kg

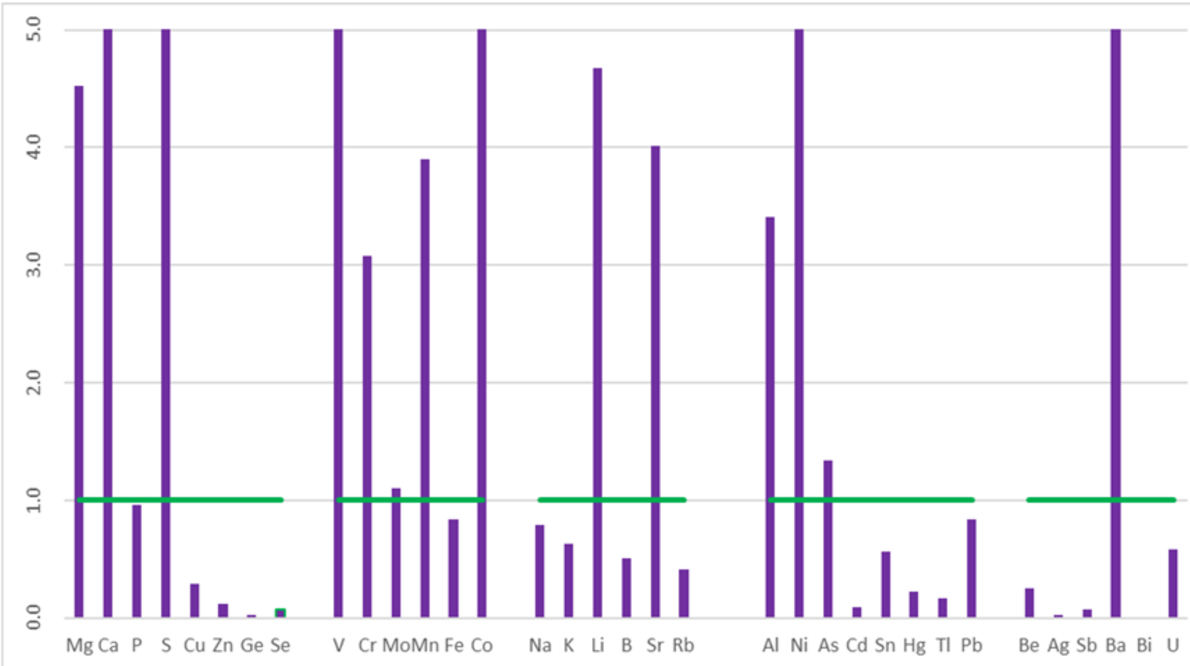


Figure 3. Metabolic profile of different chemical elements in the hair

Low content of chemical elements	**Cu, Zn, Ge, Se, Fe, Na, K, B, Rb, Cd, Sn, Hg, Tl, Pb, Be, Ag, Sb, Bi, U**
Normal content	**P**
High content of chemical elements	**Mg, Ca, S, V, Cr, Mo, Mn, Co, Li, Sr, Al, Ni, As, Ba**

The results were compared with trace element content in hair of reference man (9) and with few literature data (10-14). According to these, in the hair sample of the respondent in our study, we conclude: (Figure 3):

- low content of: Cu (5,3<24 mg/kg), Zn (21,7<180mg/kg), Ge (0.001<0.035mg/kg), Se (0,06<0,825mg/kg), B (0,44<0,9mg/kg), Fe (9,6<11,5mg/kg), Na (107<135mg/kg), K (26<41,5mg/kg), Rb (0,04<0,096mg/kg), Cd (0,005<0,05 mg/kg), Hg (0,091<0,4 mg/kg), Tl (0,0005<0,002 mg/kg), Pb (0,50<0,8 mg/kg), Be (0,005<0,02 mg/kg),Ag (0,022<0,15 mg/kg), Sb (0,002<0,066 mg/kg), Bi (0,14<0,6 mg/kg), U (0,03<0,06 mg/kg).

- high content of: Mg (215>77,5 mg/kg), Ca (2379>475 mg/kg), S (393225>47000 mg/kg), V (0,32>0,042 mg/kg), Cr (2,5>0,525 mg/kg), Mo (0,039>0,035mg/kg), Mn (1,33>0,34mg/kg), Co (6,2>0,0225mg/kg), Li (0,63>0,135mg/kg) Sr (16,3>4,1mg/kg), Al (13,6>7mg/kg), Ni

(2,7>0,2mg/kg), As (0,080>0,060mg/kg), Ba (5,3>2 mg/kg).

DISCUSSION

Quantitative analyses of chemical elements present in the hair can help determine certain physiological conditions in the body that may be associated with stress, unbalanced diet, altered homeostasis. ICP-MS method is especially used for biomonitoring the presence of heavy metals in the working or living environment (5, 11-14). Such analyses or screening tests have certain limitations and are therefore supplemented by other laboratory tests and medical examinations by a physician. Fu and Xi (1) observe that, occupational exposure to heavy metals occurs because of using these metals in a variety of industrial processes and/or a variety of materials, including color pigments and alloys. A series of adverse effects on human metabolism has resulted from exposure to heavy metal-contaminated drinking water, which has been recorded from around the world. The general mechanism of heavy metal toxicity is through the production of reactive oxygen species, the appearance of oxidative damage, and subsequent adverse effects on health (11-14). Conclusions of Singh et al. (5) are: presence of heavy metals in the body can result from consuming different foods and metabolic differences between individuals. Heavy metal contamination of vegetables cannot be underestimated as these foodstuffs are important components of human diet. Vegetables are rich sources of vitamins, minerals, and fibers, and have beneficial anti oxidative effects. However, intake of heavy metal-contaminated vegetables may pose a risk to the human health. Heavy metal contamination of food is one of the most important aspects of food quality assurance. Heavy metals are no biodegradable and persistent environmental contaminants, which may be deposited on the surfaces and then absorbed into the tissues of vegetables (5). Gellein et al. (9) conclude that trace element analysis of human hair has the potential to reveal retrospective information about an individual's nutritional status and exposure. As trace elements are incorporated into the hair during the growth process, longitudinal segments of the hair may reflect the body burden during the growth period.

Therefore, the ICP-MS can deliver valuable information about our state of health, the application of certain drugs and diagnosis of some diseases (15). They can be used for further research and medical examinations of the respondent. The obtained results or quantitative analyses of chemical elements in the body, indicate or enable early diagnosis of certain diseases and facilitate their further treatment and therapy. The level of metals can also be affected by seasonal variations or synergistic and antagonistic effect, for instance (16). However, current techniques including plasma (ICP-AES or ICP-MS), are more and more commonly applied for multi-element studies (7, 17) especially in the field of human biomonitoring studies and occupational exposure to metals (18-27). But it is necessary to elaborate a standardized methodology of human hair material treatment, sample preparation (including washing) and to evaluate reference values, which will take into consideration main parameters affecting elemental composition of hair. The proposed ICP-MS method for analysis of multiple chemical elements is a noninvasive method of investigation and it can be employed in routine analysis, which can extend the use of hair analysis for therapy, occupational, nutritional and toxicological controls. With this case report we want to emphasize the importance and significance of ICP-MS method as a powerful alternative to the usual bioanalytical methods in human biomonitoring studies.

Acknowledgment:
None declared.

Conflicts of interest:
The authors declare that there are no conflicts of interest.

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