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Analytical methodology

In search of decoding the syntax of the bioelements in human hair – A critical overview

Berislav Momčilović[a,*], Juraj Prejac[b,c], Anatoly Viktorovich Skalny[d,e,f,g], Ninoslav Mimica[h,i]

[a] Institute for Research and Development of the Sustainable Ecosystems (IRES), Srebrnjak 59, 10000, Zagreb, Croatia
[b] University Hospital Centre Zagreb, Department of Oncology, Kišpatićeva 12, 10000, Zagreb, Croatia
[c] University of Zagreb, School of Dental Medicine, Gundulićeva 5, 10000, Zagreb, Croatia
[d] RUDN University, Miklukho-Maklaya str. 6, Moscow, 117198, Russia
[e] Orenburg State University, Pobedy avenue 13, Orenburg, 460018, Russia
[f] Yaroslavl State University, ul. Sovetskaya 10, Yaroslavl, 150000, Russia
[g] All-Russian Research Institute of Medicinal and Aromatic Plants, Grina str. 7, Moscow, 113628, Russia
[h] University Psychiatric Hospital Vrapče, Bolnička cesta 32, 10090, Zagreb, Croatia
[i] School of Medicine, University of Zagreb, Šalata ul. 3, 10000, Zagreb, Croatia

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ABSTRACT

The principles and practice of assessing the human body nutritional status or its environmental exposure through hair bioelement analysis are presented; herein the term "bioelements" is used as a common denominator for the major elements, trace elements and ultra-trace elements that are found in the human body. The accumulation of bioelements in the hair followed the statistical Power Law and the resulting sigmoid curve can be zoned into five regions in the ascending order of abundance (Low, Marginal, Adequate, High, and Excessive). The Adequate linear region of the bioassay sigmoid curve may be further subdivided into Low adequate, Recommended, and Ample adequate sub regions in a 60:30:10 ratio. Phosphorus was the most invariant bioelement since its hair concentration varies minimally regardless of the geographical place of living, the twenty years' time interval between the analyses, sex, race and instrumentation, i.e., atomic absorption spectrometry (AAS) atomic emission spectrometry (AES), and inductively plasma mass spectrometry (ICP MS). The osteotrophic (bone seeking) bioelements: Ca, Mg, and Sr, were 2.5 times more abundant in the hair of women than men. Two principal electrolytes of the body (Na, K) of the multi-bioelement hair profile were markedly increased in the depressed subjects diagnosed according to the American Psychiatric Association MSD-IV classification criteria. This increase in the hair Na and K of the depressed subjects was also associated with the decrease of vasopressin in the peripheral blood. The factor analysis revealed strong association of depression with sex (women > men in a 2.5:1 ratio), and with the metals from the Nieboer-Richardson series which form strong covalent bonds with proteins. We propose that the biological roots of depression are related to the non-specific impairment of the intracellular osmotic balance and ionic gradient due to the $Na^{+}K^{+}$ATPase failure from whatever cause acting either separately or in combination. We also put forward the idea of how children's autism may be related to a disproportional growth rate of various organs and tissues if children are fed up to their maximal genetic growth capacity. Finally, we have suggested the hypothesis on how the syntax or integration of the internal metabolic wiring of the bioelements in the body may occur. We have suggested the hypothetical existence of two complex distinct five-bioelement "rotors", the P-rotor and the N-rotor, where the P-rotor integrates the *mileau interior* (Na, K) ions with the perception/excitability (Mg, Ca) ions. Thus, the complex five element interdependence is cross related to P which provides the energy from the phosphorus of the DNA nucleotide backbone. The hair multi-bioelement profile analysis allows us to envisage the more complex structural metabolic features that bioelements are playing in our bodies.

* Corresponding author.
E-mail addresses: ires@ires.hr, berislav.momcilovic@gmail.com (B. Momčilović), jprejac@kbc-zagreb.hr (J. Prejac), skalny3@microelements.ru (A.V. Skalny), ninoslav.mimica@bolnica-vrapce.hr (N. Mimica).

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1. Introduction

The aim of this critical overview of our research on bioelements over the years is to show the mutual inter-relations between hair growth and its bioelement composition, and how it may help us to develop appropriate reference standards for the assessment of the nutritional status of bioelements in the body and to assess the health impact of their environmental exposure. Also, we have attempted to relate these findings within the context of (a) gender difference, (b) the biological roots of human depression and autism, and (c) to provide for a more deep insight into the inner wiring, or syntax, of the bioelements in the physiological metabolic processes within the human body. Indeed, if we assume the elements to be the specific letters of the alphabet of life, and then the clustering or paring of the bioelements having similar chemical and/or physiological properties of a words lexicon, then combining such words into meaningful sentences would be their metabolic syntax. Here we have used the term "bioelements" in the broadest sense so as to include major elements, trace elements, and ultra-trace elements both essential and non-essential. However, we have refrained from qualifying an element of being toxic, since every element may be toxic depending upon its concentration [1] and a rate at which an element is administered [2]. It is pertinent to note here that discussions about a proper name for the discipline which would include major elements, trace elements, and ultra-trace elements in biological tissues, what we have here collectively named bioelements, have been with us for decades without a solution [3]. Today, many of the elements which decades ago were named as "trace elements" can be very well quantified so that the associated term "trace" is now obsolete. Moreover, in multielement analysis we sometimes analyze elements from all the above enumerated categories at the same time simultaneously.

2. Hair tissue as a long-term biological indicator of nutritional status and internal environmental exposure

Biochemically, hair is a growing keratin protein polymer fiber [4], a wool-like specific human body tissue, which may be used as s long-term biological indicator biopsy tissue of choice for assessing the bioelement nutritional status and biomonitorig of internal contamination after environmental exposure [5,6]. Hair is easily accessible; its collection may be done *in vivo*, collection is painless, and hair can be easily stored and transported to the places where the adequate analytical equipment and trained personnel are available. Human scalp hair contains about 80,000–120,000 hair follicles and every follicle generates a complex hair fiber which is some 0.2 mm in the diameter, whereas the hair growth rate is about 1 cm per month or 0.3 mm per three days [7]. One cm of hair is equivalent on some 30 liters of urine when compared on the same time scale; even a five day urinary collection is a daunting organizational and labor-intensive task [8]. The hair growth rate appears to be fairly constant over a life time, but the number of active hair follicles decreases with aging [9]. The inner structure of hair is complex, and it contains all the known elements from the Periodic table, but in different concentrations and in various mutual inter-relationships. Indeed, the range of observed concentration of different bioelements in hair (μg g^{-1}) covers the span of 10^4 for the most abundant calcium to the 10^{-3} of rarely detectable … Be, Pt, and Tl (Fig. 1) [10].

Hair grows from the hair follicle bulb which is a unique tissue structure visually reassembling the solid multicellular synapse (Fig. 2) [9]. Hair follicle bulb cells are the most rapidly dividing cells in the human body, next only to the fast growing bone marrow hematopoietic cells [11]. However, the hair growth is not a continuous linear process, but a dynamic and discontinuous "stop and go" activity where the periods of active growth (*anagen*) are interspaced with periods of hair fiber growth cessation and hair bulge involution (*telogen)* (Fig. 3). What induce and regulate the process of separating the mesodermal hair follicle from the hair bulb, which has retracted into the hair bulge ectoderm, and then again unite the hair bulge back from the ectoderm with the mesodermal hair follicle bulb, is still obscure [12,13].

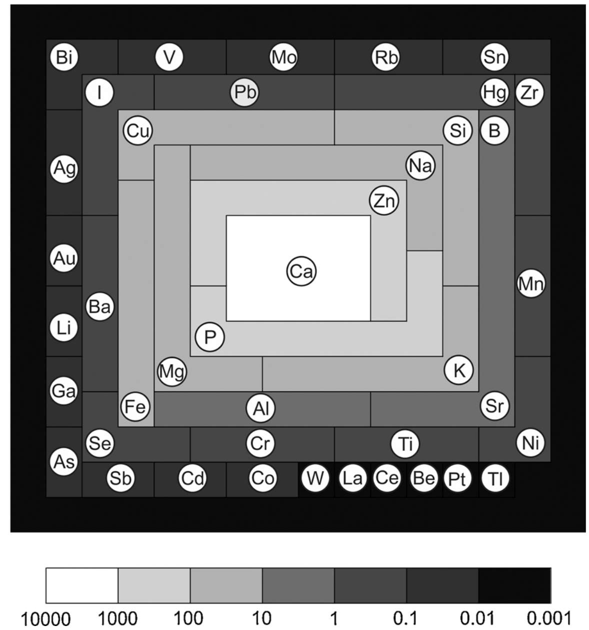

Fig. 1. Hair bioelement abundance (arbitrary s scale). [5].

3. Deposition of bioelements in the hair is a power law guided saturable process

As already shown (Fig. 1), the entire "cosmos" of the Periodic system of elements may be found in human hair. Thanks to the advancement of modern analytical instrumentation, like the ICP-MS, it is possible to analyze simultaneously a whole array of bioelements accurately down to the ppb level. However, over the passing decades the opinions about the usefulness of hair bioelement analysis for human health protection and clinical practice has gone through up and down cycles, ranging from naming it a "new window into the world of human diseases" [14], to be just a "scum" [15]. However, now we consider the hair to be a reliable long-term biological indicator tissue for assessing the bioelement status and metabolism [16,17]. Indeed, when we look at hair bioelement data frequency distribution on an arithmetic scale, we see that such distributions are generally skewed and curtous. We have observed that the authors of numerous studies have arranged their data on a linear scale prior to statistical analysis. Therefore, we took another approach and the first step was to log transform the observed data what have resulted in the familiar Gaussian bell shaped curve of data frequency distribution, as demonstrated for hair iodine as a long-term bioindicator tissue, and the short term biological indicator tissues of whole blood, and urine (Fig. 4). The comparative data on hair and whole blood iodine are ours [18], whereas the urinary data are from the WHO Cameroon study [19]. Next, we used such a log transformed data to transform the Gaussian bell-shaped curve into the sigmoid curve of median derivatives (Fig. 5) (Appendix A) with a statistical package OriginLab Corp., OriginPro Version 8.0, Northampton, MA. Such sigmoid curve bioassay methods are a standard biochemistry tool [20] which is mostly used to describe the physiological saturation processes such as hemoglobin saturation with oxygen [21], and in pharmacology [22] and toxicology [1]. Such a sigmoid curve or sigma, may be "zoned" [23] in several distinct segments which may be used to assess the bioelements nutritional status or to evaluate their environmental exposure. The sigma starts with an overt bioelement deficiency, rises to marginal deficiency, enters the range of adequate nutrient intake and/ or allowable exposure, then climbs further up to the really high intake of an bioelement, and ends up with an excessively high intake and