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"Reference values" of trace elements in the hair of a sample group of Spanish children (aged 6–9 years) – Are urban topsoils a source of contamination?

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ABSTRACT

Human hair is used as a biomonitor to evaluate the environmental exposure to contaminants in the individual. However, the use of human hair is controversial, mainly because reference levels for pollutants in hair have not yet been set. In the case of Spain, few biomonitoring studies have involved infants and children. A biomonitoring study was conducted to investigate the possible normal values of trace elements of toxicological concern in children aged 6–9 years from the city of Alcalá de Henares, Community of Madrid (Spain), following the methodology and strict inclusion criteria previously developed by our group. Levels of Al, As, Be, Cd, Cr, Cu, Hg, Mn, Ni, Pb, Sn, Ti, Tl, V and Zn were monitored in scalp–hair from 117 healthy children (47 boys and 70 girls) between April and May of 2001. The levels of trace elements here described could be considered as possible "reference values" for children aged 6–9 years resident in the Community of Madrid. These values might also be selected as a preliminary screening tool to evaluate if a Spanish child has been exposed to any of the contaminants studied here. This study also investigated whether local urban topsoils were a source of metals for this population.

1. Introduction

Exponential urban and economic development has resulted in human populations settling in urban areas, and as a result being exposed to pollutants. Inorganic environmental pollutants such as metals and metalloids are progressively increasing in the urban environment due to their uses and inorganic characteristics. Trace elements can induce toxic, carcinogenic effects or oxidative stress even at long-term low-dose levels of exposure, and urban citizens can be long-term exposed to low levels without discernible symptoms (Peña-Fernández, 2011; Peña-Fernández et al., 2014a; Varrica et al., 2014).

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In the metabolism of any living organism, removing toxic substances is a prerequisite for life. The elimination of a toxicant is defined as the net decrease of the amount in the body. In human beings, excretion is the passage of the toxic susbstance inside the body to the external environment via excreta: urine, faeces, sweat, etc. Many toxic xenobiotics such as metals and metalloids have a particular affinity for sulfhydryl groups. These groups are mainly in keratinised tissues such as nails or hair (Cespón-Romero and Yebra-Biurrun, 2007; Kordas et al., 2010; Rodrigues et al., 2008; Unkiewicz-Winiarczyk et al., 2009a,b). Furthermore, it has been shown that human hair is one of the major excretion vehicles for trace elements that have been absorbed and metabolised (Cespón-Romero and Yebra-Biurrun, 2007; Sukumar, 2002). Therefore, these micro-pollutants are found in human hair at a concentration about 10 times higher than other biomarkers such as urine, blood or plasma (Olmedo et al., 2010).

Currently there is no scientific information on the kinetics of incorporation of trace elements in the hair (Pragst and Balikova, 2006; Rodrigues et al., 2008). This makes it difficult to establish reference values for these substances in human hair. The presence of metals and metalloids in hair may be: (i) because metals are caught by hair directly from the bloodstream (known as endogenous elements); (ii) because metals are incorporated by the hair once excreted by the sebaceous glands and/or sweat (semi-exogenous elements); or (iii) due to external contamination with elements in the environment: air, water, soil, dust, cosmetics, etc. (exogenous elements) (Herber et al., 1983; Hopps, 1977).

Human hair can be used as a biomonitor to assess the environmental exposure to metals and metalloids in human beings (Bartell et al., 2004) and is considered a good matrix for estimating environmental exposures prior to more extensive and expensive studies involving the collection of blood and urine (Schuhmacher et al., 1996; Liu et al., 2008; Sanna et al., 2008; Lemos and de Carvalho, 2010; Sanna and Vallascas, 2011; Varrica et al., 2014). Hair offers several advantages in human biomonitoring: is stable and easily accessible for sampling analysis (Dongarrà et al., 2012), reflects long-term exposure (Gil et al., 2011), and is better accepted by young people than other matrices such as blood. Hair is also considered a good biomonitor of environmental exposure for children, that can be more sensitive to environmental contamination (Callan et al., 2012; Demetriades et al., 2010) due to their less developed blood-brain barrier (Jarup, 2003), and the fact that they breathe more air and consume more food per unit weight than adults (Moya et al., 2004). Moreover, young people could be more likely to be affected by contaminated soils due to their higher sensitivity, higher absorption rates from the gastrointestinal tract and behavioural traits (Johnsson and Bretsch, 2002; Ljung et al., 2007; Madrid et al., 2008; Yáñez et al., 2003).

Despite these advantages, human hair has several limitations that have been discussed comprehensively in Peña-Fernández (2011): (a) several factors influencing metals and metalloids concentrations in hair such as age, gender, and life-styles; (b) the kinetic of incorporation of trace elements in hair is not well-known; and (c) some trace elements have not shown correlation with other biological matrices. Therefore, the use of hair as a biomonitor can be controversial, especially due to the lack of information available to define a normal range for trace element levels in the general population (Barbosa et al., 2005; Kilic et al., 2004; Kordas et al., 2010). However, the use of the methodology and strict inclusion criteria developed by our group could facilitate the use of human hair as a screening tool in environmental biomonitoring studies to help to identify individuals with higher exposures to metals and metalloids (Peña-Fernández et al., 2014a).

Due to the limited availability of information on levels of metals and metalloids in hair in Spain, a comprehensive study of Human Bio-monitoring (HBM) in hair of school children and teenagers was undertaken in one of the largest cities in the Community of Madrid, Spain: Alcalá de Henares (Peña-Fernández, 2011). This paper reports the results from the children aged 6–9 years.

The aims of the present study were: (a) to determine the reference values of aluminium (Al), arsenic (As), beryllium (Be), cadmium (Cd), chromium (Cr), copper (Cu), mercury (Hg), manganese (Mn), nickel (Ni), lead (Pb), tin (Sn), titanium (Ti), thallium (Tl), vanadium (V) and zinc (Zn) in the hair of healthy school children (6–9 years) from Alcalá de Henares, Madrid, Spain; and (b) to determine if urban metal-topsoils are a significant source for this particular group of children, since these soils are considered as a "target" for contaminants, especially for metals and metalloids. In urban environments, trace element concentrations in top soils can act as tracers of environmental pollution and as "health indicators" (Massas et al., 2009).

2. Material and methods

2.1. Study design and recruitment

Hair samples were collected between April and May of 2001 from healthy children aged 6–9 years of Caucasian ethnicity who had been permanent residents of Alcalá de Henares, one of the most populated cities of the Community of Madrid, Spain. Alcalá de Henares is an UN World Heritage city (latitude: 40°28′49″ N–longitude: 3°22′9″), is 35 km from Madrid city and 15 km from the international airport of Madrid-Barajas. Samples were taken following the methodology and strict inclusion criteria developed by Peña-Fernández (2011), summarised in a pilot study in Peña-Fernández et al. (2014a). Written consent was obtained from the parents or legal guardians, as well as from the schools' directors. The study was performed following the guidelines of the Helsinki Declaration.

Hair samples 1–2 cm long were cut with stainless steel scissors from the nape of the neck, close to the occipital region of the scalp. The methodology and selection criteria were developed to ensure a robust study design and use of appropriate population sample, as there are several factors that may affect the presence of trace elements in human hair. The preliminary study presented in Peña-Fernández et al. (2014a) could be the basis for further environmental studies to identify environmental contamination that can affect the health of the inhabitants of cities.